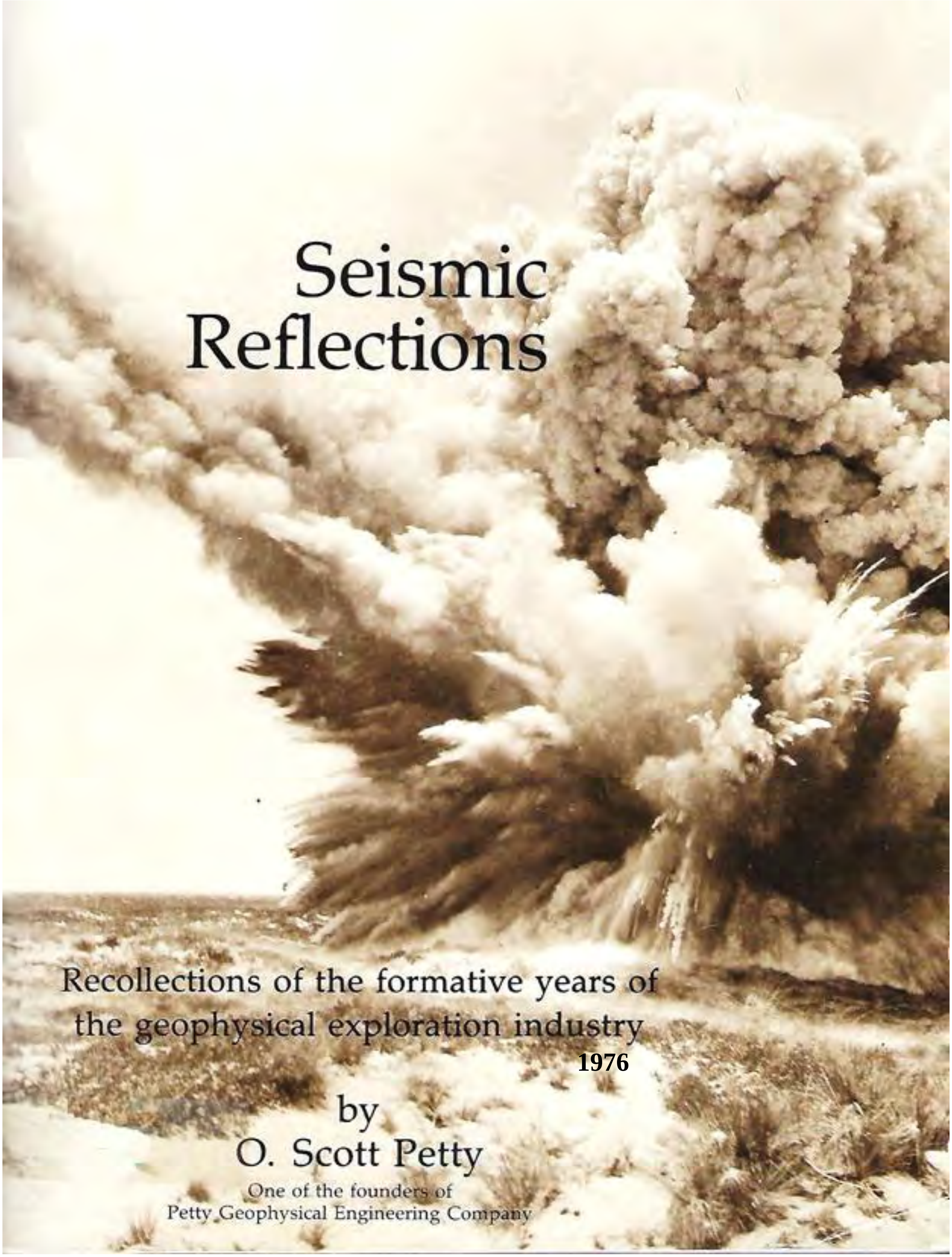
Seismic
Reflections
Recollections of the formative years of
the geophysical exploration industry
1976
by
O. Scott Petty
One of the founders of
Petty Geophysical Engineering Company

Hauling dynamite for the shot shown on the front cover.

Cover: A refraction shot in West Texas. 2,000 pounds of dynamite shot by Humble Oil & Refining Company (now Exxon) 1930

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Printed in the United States of America.

ESL

To Edwina who, for more than Fifty Years,
Put up with The Trials and Tribulations of a Geophysicist
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Foreword

From my earliest days in the petroleum industry as a fledgling observer on a geophysical crew, I recall that the Petty name was synonymous with geophysics. Little did I know at the time that I would someday have the distinct privilege and pleasure of a lasting personal association with one of the true industry pioneers, Mr. O.S. Petty. Needless to say, I consider it a privilege and an honor to have this opportunity to write the foreword to a book in which Mr. Petty reflects on his experiences and those of his brothers during the formative years of the geophysical industry.

Few men can appreciate the trials and tribulations that the founders of this new industry had to overcome, nor can they appreciate the exhilaration and pride that these men experienced when their very crude instruments, by today's standards, were able to accurately locate and identify some of the most prolific oil fields ever found in the world.

Mr. O.S. Petty has been a selfless contributor throughout his lifetime to the furtherance of technology in the geophysical industry. But most important, his concern for the welfare of mankind, his devotion to the industry he helped create, and his strong feeling for family ties and lasting friendships have made him the unique individual he is.

Of the many dedicated and creative people I have had the pleasure of knowing throughout my career in the petroleum industry, I must number Mr. Petty among those who are truly outstanding. Although his technological contributions to the industry are unmatched, it is his reputation as a gentleman and humanitarian that has gained him the respect of all who know him.

B.P. Loughnane,
President and Chief Executive Officer,
Geosource Inc.

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Preface

In the lobby of the Petty-Ray Geophysical and Mandrel Products Divisions of Geosource Inc. in Houston stand two cabinets of early Petty geophysical instruments dignified by a bronze plaque placed there by Geosource which reads "THE PETTY GEOPHYSICAL MUSEUM displayed through the courtesy of O. Scott Petty. This

collection of original geophysical instrumentation was developed and used in the 1920's by O. Scott Petty and his brothers, Van A. Petty and Dabney E. Pelly, who in 1925 founded the Petty Geophysical Engineering Company. In 1973 the Petty Geophysical Engineering Company merged into Geosource Inc. and integrated with the Ray Geophysical Division to form Petty-Ray Geophysical."

This book is published for the purpose of presenting some additional technical and historical details about the instruments on display in the museum and to give a brief history of Petty Geophysical Engineering Company through some interesting stories and events as I remember them.

It has been suggested to me many times that a narrative of my experiences in the early days of Petty Geophysical Engineering Company should be preserved in printed form. It was due to the special request of Scott Petty, Jr., B.P. Loughnane and some of my associates in Geosource Inc. that I decided to undertake the task. I was not without misgivings for I have no false notions about being a writer. I am a geophysicist. So, with some qualms, I send this book on its way. If the indulgent reader gets as much pleasure out of reading it as I got out of putting it together, we shall both be happy.

Only a smattering of technical information can be presented in a brief treatise such as this but to those few who might be more deeply interested in the history of the evolution of geophysical hardware and software the author extends an invitation to visit him for a discussion of such.

I wish to express my deep appreciation to those whose help was invaluable in bringing this publication to life: Mr. Scott Petty, Jr., Mrs. Edwina H. Petty, Mrs. Louise James Petty, Mr. Lewis A. Davis, Mr. W. Harry Mayne, Mr. Dennis R. Hoerster, Mrs. Iris Shockley Haese and others.

O. Scott Petty

San Antonio, Texas
September 16, 1976.

On February 10, 1976, dedication ceremonies for the Petty Geophysical Museum were held in the lobby of the Robert H. Ray Building in Houston. Speaking for the Petty family was Scott Petty, Jr. shown at right next to the commemorative plaque.

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Part I

Events in The Early Years

A Bit of History

In 1841 David Milne invented an instrument for recording and measuring the movements of the ground during an earthquake and called it a seismometer, the earliest seismological term. A few years later the name seismograph was given to an instrument erected in 1855by L. Palmieri in the observatory on Vesuvius.

The first practical use of the seismograph for anything except recording earthquakes happened during World War I when German scientist Dr. L. Mintrop invented a portable seismograph for the German army to use for locating Allied artillery. He would set up three seismographs in known positions along the battle-front opposite which there was an Allied gun bombarding them. When a gun fired, a record would be made of the earth vibrations and the exact location of the gun could be calculated so accurately that often the first shot from a German gun would make a direct hit.

The Germans found that errors were introduced into their distance calculations because velocities varied with the geological formations through which the vibrations passed, and certain assumptions about geology had to be made to compute the distances. After the war, Dr. Mintrop decided to reverse the process. He would set off a charge of dynamite and record the vibrations produced in the earth on his same portable seismographs, but this time he would measure the distances and compute the geology. And that was the birth of the present day seismograph contracting industry. He named his company Seismos. In 1924, the Gulf Production Company brought one of Dr. Mintrop's crews to Texas to hunt shallow salt domes. This brief explanation will help you better understand my brother Dabney's letter to me.

The Letter That Sparked The Beginning

While working as a structural engineer in Dallas, I received a letter from my brother Dabney, who was Associate State Geologist for the Bureau of Economic Geology in Austin. I quote from the letter dated March 25, 1925: "Scottie I am going to enclose a copy of a paper that the Seismos people put out - who are furnishing the Gulf with their seismographs. There are only three companies using them now in the Gulf Coast. But the others are working on them and no doubt will soon be using them.

"I am wondering if you would spend a few of your spare moments in studying the method and see if you can learn to interpret the readings. I am going to be blown up so far as economic geology goes soon if I don't get lined up with one of these instruments. If you could learn how to use one we could do a great business doing consulting work.

"So if you can figure it out by this summer when we both get a vacation we can get an instrument - or I will have one already - and we could spend a few weeks shooting the known domes and perfecting the results. But a person would have to have the method fairly well figured out before starting."

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April I, 1925, I replied to Dabney's letter as follows: "Your letter received, also the enclosed copy of report, both of which were very interesting indeed. I at once visited the Public Library here and got all available books on the seismograph and earthquake vibrations and have been doing some heavy thinking.

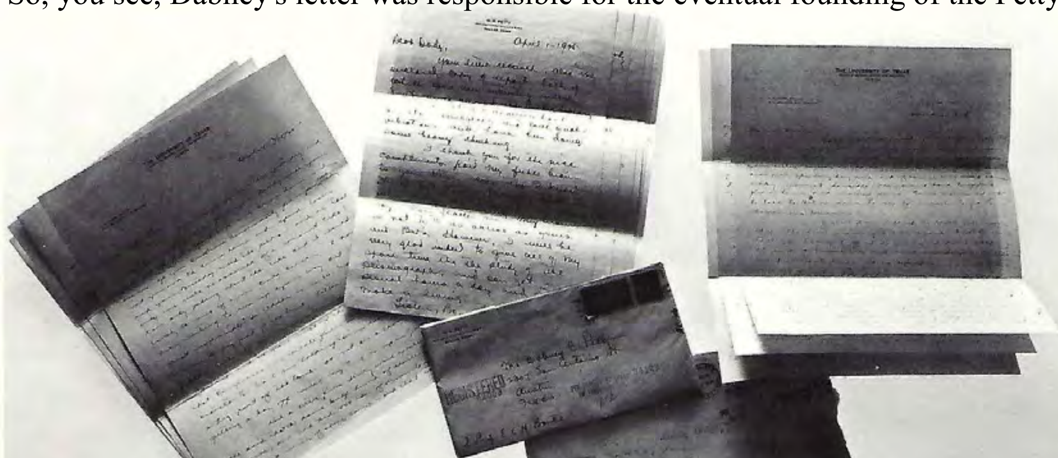
"I'm so ignorant on the whole subject that I don't even know the elementary principles and theories but 1've got an idea. It occurs to me that if we had a seismograph that we could operate without using great quantities of dynamite - no dynamite at all, I mean - we would be able to put it all over these big companies. Do the Germans employ the vacuum tube in their seismograph? If not, I believe we are fixed!! Listen.

"A vacuum tube is an invention of radio in the past few years and is a marvelous instrument. It can be used for detecting very small electrical disturbances etc., and making small measurements of all kinds. To give you an idea how sensitive they are, imagine a bar of steel one-half inch in diameter and a foot long clamped in a vise. Imagine a fly lighting on the end of it. A vacuum tube is sensitive enough to measure the deflection of the bar of steel due to the weight of the fly!

"My idea is simply this. Let's try to invent a seismograph using a vacuum tube to detect the earth vibrations so that it will be sensitive enough to register the vibrations made by simply dropping a heavy chunk of lead on the ground. I believe a machine could be made sensitive enough to do this though I am not sure. If the Germans are already using the tube then they have already refined it; but if they are not then I believe we could incorporate one in it and make it ten times as sensitive. It would be a big task but worth it if it could be done. If you will get me all of the dope you can on the subject I will do my best to try to devise a way to get one of these noiseless seismographs.

"My idea is that the big companies are not thinking about improving on the German machine - they are simply trying to get them and learn to operate them as they are. And the Germans probably aren't trying to improve on it if they are doing a landslide business as they now are, so it might be that we could slip in under them and be first to develop the idea." (It was later determined that vacuum tubes were not used in the German instruments.)

So, you see, Dabney's letter was responsible for the eventual founding of the Petty Companies.



We Resigned Our Positions

A few days after the preceding correspondence, Dabney resigned his position as Associate State Geologist with the Bureau of Economic Geology at Austin and I resigned mine as Structural Engineer for R. O. Jameson in Dallas. In about 30 days, we got together in San Antonio as happy as if we had good sense. Little did we know about the trials and tribulations that lay ahead; we thought it would be rough as we would be breaking into a new science but we underestimated! Luckily we couldn't foretell the difficulties or we might not have tried it!

Neither Dabney nor I had any money. Our father agreed to loan us up to $5,000 to get started.

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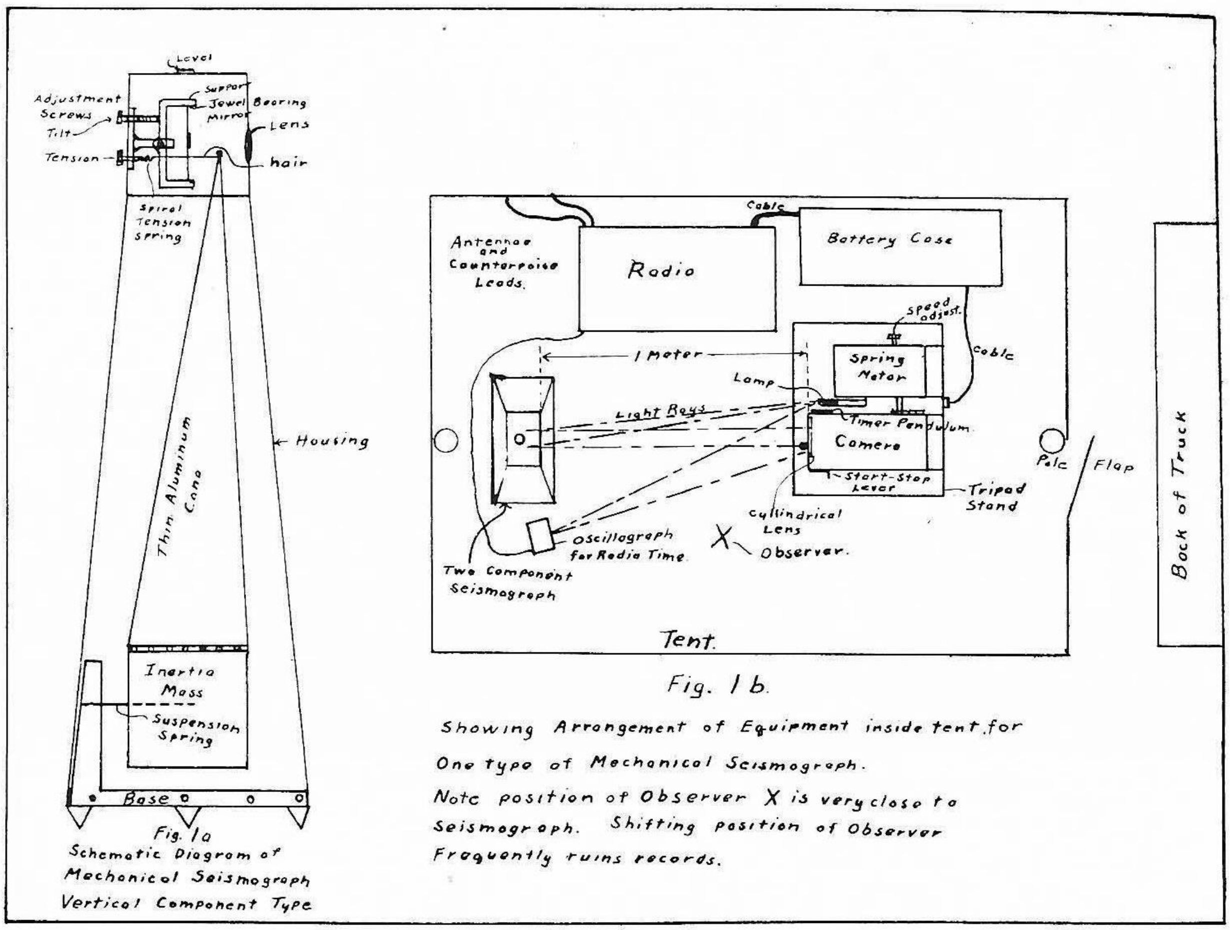
When we first started our research, our aim was to develop instruments which would give us a faithful reproduction of seismic waves as we planned to study not only travel times but wave forms and amplitudes as well. We also wanted our timing mechanism to be as perfect as possible. The point was, as we saw it, the Germans had been shooting the Gulf Coast for well over a year in the search for shallow salt domes and should by that time have mapped a large percentage of them.

Mintrop's seismograph was a unique and practical little machine for the military use for which it was invented, and it did a good job locating shallow salt domes with huge charges of dynamite. However, it was too crude for mapping deep seated domes or anticlines of reasonable relief.

The machine actually consisted of a steady mass suspended by a horizontal leaf spring. The relative movement between earth and steady mass was mechanically amplified by a long shaft attached to the top of the steady mass which rotated a small mirror. Additional amplification was obtained optically by reflecting a beam of light off of the mirror to a strip of photographic paper pulled by a hand-cranked camera.

During operation, a person sat by the seismograph and cranked the camera. Obviously, not much sensitivity could have been used had it been available because the movement of the operator would have caused too much ground unrest.

The creation of our first set of instruments was a harder job and took longer than I had anticipated. My basic idea was simple. I would get an electronic circuit in which the plate current in a vacuum tube varied as the distance between two condenser plates. The condenser plates were polished steel discs about the size of a silver dollar. I would attach one plate to a steady mass and the other plate through a framework to the ground. As the ground vibrated, the distance between the plates would vary in the same way. This device would be the vibration detector and would be placed about 100 feet from the observer.



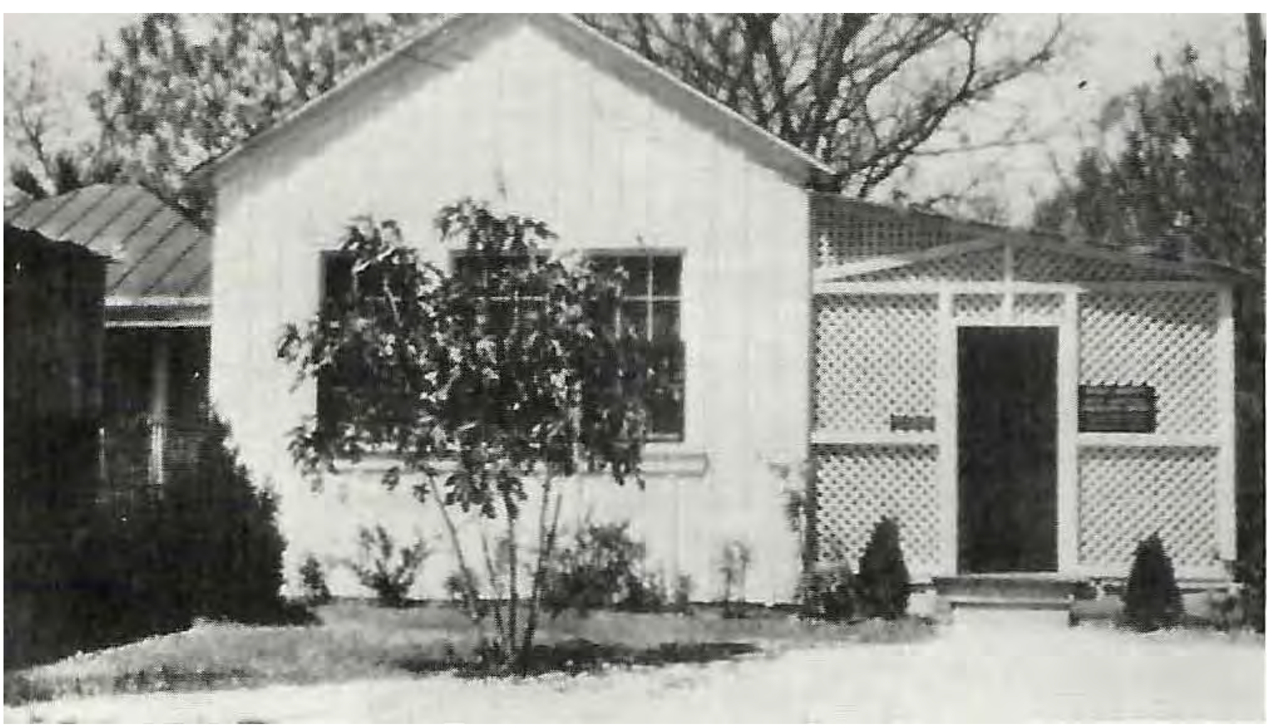
Mintrop's mechanical seismograph as illustrated by Mark C. Malamphy in "Factors in Design of Portable Field Seismographs", The Oil Weekly, March 22, 1929.

My plan was to amplify the fluctuating electrical current through a vacuum tube amplifier; then pass it (by means of a transformer) through a very fine copper wire that hung in a very powerful magnetic field. By means of a lens system, a shadow of this wire, in the form of a moving black dot, would be cast on a strip of photographic paper pulled at constant speed by a spring motor. A time marker would put cross lines on the paper each one-fiftieth of a second.

All went well until I tried to hook the detector circuit to the amplifier. None of the electronic experts could offer helpful advice. In fact, just after I had accomplished the hookup, I received a bulletin from the University of Tokyo telling why it could never be done!

Our first 6 months were the hardest for we not only had technical problems but financial ones as well. Our salaries had ceased when we quit our jobs. Our folks helped out by giving us room and board for free and furnishing us a place to work. They lived in the beautiful old family home at # 10 Tenth Street in San Antonio. They turned the third floor over to us, which we used as our shop and laboratory, and also a large basement, which we used in testing our seismograph as development progressed. The location was ideal for we found that trolley cars, passing over bumps in the tracks two blocks away, set up helpful vibrations in the earth, which were fairly uniform in nature. *3*

The birthplace of Petty Geophysical Engineering Company, #10 Tenth Street, San Antonio, Texas.



Petty's first shop and laboratory.

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A Corporation Is Founded

Our little enterprise was a family effort as my wife Edwina donated her services for free and was absolutely invaluable as my shop and field assistant. I will never understand how she put up with what life dished out to her in those trying days and nights when we worked pretty much around the clock.

By the end of September Dabney and I had spent our $5,000 and we weren't far enough along to accept commercial work. We took stock of our financial situation and it was then that my older brother, Van (an attorney and independent oil operator), volunteered to step into the picture and help. Van suggested that we form a corporation and that Dabney and I each take one-quarter of the stock for what we had done to date (value $2,500 each) and the balance be sold to members of our family who purchased it as follows: my father, $l,000; my mother, $1,000; Van, $2,000; my wife, Edwina, $800; and her sister, Emily Harris (now Mrs. Herman Knauss), $200. Van did all of the legal work in setting up the corporation. Thus the Petty Geophysical Engineering Company came into existence.

Field Research Begins

By November, 1925, our instruments and theories were ready for field testing and our first shot in the Hill Country in Bandera County was a huge success. We recorded a twenty pound shot of dynamite in the Edwards limestone at a distance of about 2 miles. This field experience showed us where we could make some beneficial changes in our instruments and so we spent the first part of the winter doing that.

Now that our instruments were ready the next thing on the program was to lease acreage on a known salt dome and learn how to interpret seismograph records. We chose Stratton Ridge in Brazoria County, Texas. Our acreage was partly on and partly off of the salt. We used an old abandoned farm house with cracks in the floor and walls for our headquarters. There were three in our party as we hired an unemployed blacksmith to help us.

Petty's first field camp at Stratton Ridge, an abandoned farm house with big cracks in the floors and walls.

Conrad (Pop) Reichert was a very ingenuous man and was to be our shooter. He was a good choice as he stayed with us for about 25 years until his retirement, during some of which time he was in charge of our shop and laboratory.

The winter was one of those unusually cold, wet ones when the ground was frequently covered with ice, snow, or mud. We did our surveying by day and most of our shooting at night when ground noises were minimal. We didn't get much sleep, often only a few hours a day.

It was a wonder we did not all die of flu as there was a terrific flu epidemic raging in Texas, the worst since 1918.

We were overworked, wet, and cold most of the time as well as poorly fed. However, the rugged primitive life must have had a therapeutic effect as we never had so much as a cold whereas our families in comfortable quarters in town all had the flu.

We did all sorts of shooting: refractions, reflections, big shots, little shots, long lines, short lines, profiles, fans, the works. We recorded all three components of wave motion: vertical, horizontal in line with the shot, and horizontal at right angles to that line. We studied all of the different kinds of waves: primary (compressional), secondary (shear), Rayleigh, Love, refracted, and reflected. And we learned lots! We studied wave forms and amplitudes with great care as we hoped to find an easier, cheaper, and quicker method of finding salt domes than the Germans were using - and we did!

We were thrilled to death when we found that we could record good salt dome records with as little as 20 pounds of dynamite whereas the Germans were using several hundred pounds to do the same thing. We had theorized that Rayleigh waves (ground roll) should be inhibited over salt domes because they are surface waves travelling along interfaces between geological formations (i.e. clay. sand. shale contacts, etc.), and, over salt domes, these formations are penetrated or uplifted by the salt. We found this theory to be a fact and made great use of Rayleigh waves in our explorations over the next few years.

PORT

s, Thursday, January 28th., 1926

Doodle Bugging Near Freeport

Two young men have been in Freeport this week directing a doodle-bug test near here, feeling out the country for salt domes and oil pools.

These two gentlemen asked the Facts not to give their names in connection with this story or describe their doodle bug or seismograph instrument.

This seismograph machine is one that is guarded very closely. You are not allowed to examine it, nor allowed to become familiar with its tricks.

This machine registered a shock somewhat like a seismograph registers the shock caused by an earthquake.

A hole is drilled in the ground to a depth of perhaps 15 or 20 feet. Dynamite is placed in the hole and touched off. The explosion registers on the seismograph, which is located some distance, the formation of the earth in the vicinity of the test.

In this way, it is claimed, salt domes and oil fields are found.

A test has been made on the J. W. Morris tract near Oyster Creek.

The quake from the explosion was felt very keenly in Freeport and Velasco, but it is said the shock was more severe on the east side of Oyster Creek.

Other tests will be made and it is hoped to get a pretty fair photograph of what is beneath the surface of the earth.

Seismographs that are located in government observatories are very delicate instruments and register quakes thousand of miles away.

These small seismograph instruments they carry around feeling for underground formations must be wonderful things. They at least get the credit of finding the salt domes at various places in this section.

*Clipping from **Freeport Facts** of a story about Petty's operation. Because of the prevailing competitive atmosphere, the paper was requested not to identify Petty.*

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Pop Reichert and his first shot hole drilling rig .The derrick was made of wood.

Pop's Close Call

At this stage of the game, we were not sure why the Germans were using such large charges of dynamite. Was it because their instruments were not sensitive enough, or did the big shots create some earth waves that smaller shots could not create. We aimed to find this out quickly, and in doing so, had an experience that was

etched so deeply on our minds that the three of us never forgot it. In fact, the memory is as fresh to me after 50 years as if it had just happened yesterday, and I must tell you about it.

Our shooter, Pop Reichert, had an extremely bad habit of sitting on a box of dynamite close to the shot point! He held a railroad watch in one hand and, in his other hand, the handle of his blasting machine, ready to fire the shot at the exact second previously agreed upon, We had no radio communications in those days,

We explained to Pop that this was fool-hardy, that we were using 60 percent straight nitroglycerin dynamite. That if a large clod of earth fell on it, he and our whole company would be wiped out He would not heed our warnings - said it was handy because he always had an extra box of dynamite with him, and it made a comfortable seat, and anyway, he wasn't afraid. We cautioned him relentlessly every morning, but it never did any good.

We had been shooting mostly 5 to 30 pound shots in deep holes, but the Germans usually used at least several hundred pounds, and we wondered if they were getting something we weren't. It was near the beginning of the job so we decided to find out before spending too much time with smaller shots. We told Pop to put 300 pounds in a hole 8 feet deep and pile all of the dirt he could on top of it for this next Shot.

We had learned that the earth was quietest about 30 minutes before dawn - wind usually died down then and few vehicles, people or animals were moving about So that was to be the zero hour.

Of course it was raining that night, dark as pitch and it was cold. Dabney and I pitched our observing tent by lantern light and set up our instruments with extra care because we did not want to waste that 300 pounds of dynamite.

It was quiet and still as death when the second hand of our railroad watch reached 4:58. We started our camera. At 4:59 ½ we held our breath and sat rigid so that our movements would not disturb the ground. Our eyes were glued to the shadow of the string of our galvanometer. We were tense, waiting for this 300 pounds of dynamite to go off with a bang. At about 5:01, the shadow vibrated, low amplitude for a few hundredths of a second indicating the salt lead, then it burst into a wide vibration indicating the primary wave. We breathed and smiled at each other but still could not move because the Rayleigh waves were rolling past. Then the air waves arrived and what a sound. At 5 o'clock in the morning it sounded like what it was the explosion of 300 pounds of dynamite. Then, in the fraction of a second, it happened! The sound of a second explosion at least five times as loud as the first one nearly shook our tent down!

Apparently Pop was not the only member of the crew who sat on dynamite as O. Scott Petty was occasionally caught resting on the ever-present boxes.

Dabney looked at me, and I looked at him, and neither of us said a word. We knew what had happened - that big clod of dirt had fallen on Pop and the dynamite. We stopped the camera and turned white. We crawled out of the tent into the rain. We were exhausted from overwork and strain. We both started crying there in the dark and the rain. It was awful! We had killed one of our best friends and wiped the company out almost before it got started.

When we had partly regained our composure, we started talking. Did Pop have a chance? None that we could think of. Could the second explosion have been something else? Nothing that we could think of. The interval between the explosions was just right for a big hunk of earth to have gone up and fallen back. We tried to convince ourselves that it wasn't so, but we couldn't.

It was two sad young men who packed their instruments into their Model T and drove silently back to camp, each with his own thoughts. It was still dark, and we were wet and cold though the rain had slackened some. Two horrors filled my mind. First, there would be the visit to the shot point. I could imagine the scene. Then we would notify the sheriff. It was a long ride back in the darkness, and it seemed longer than it was. We both hated the thought of arriving.

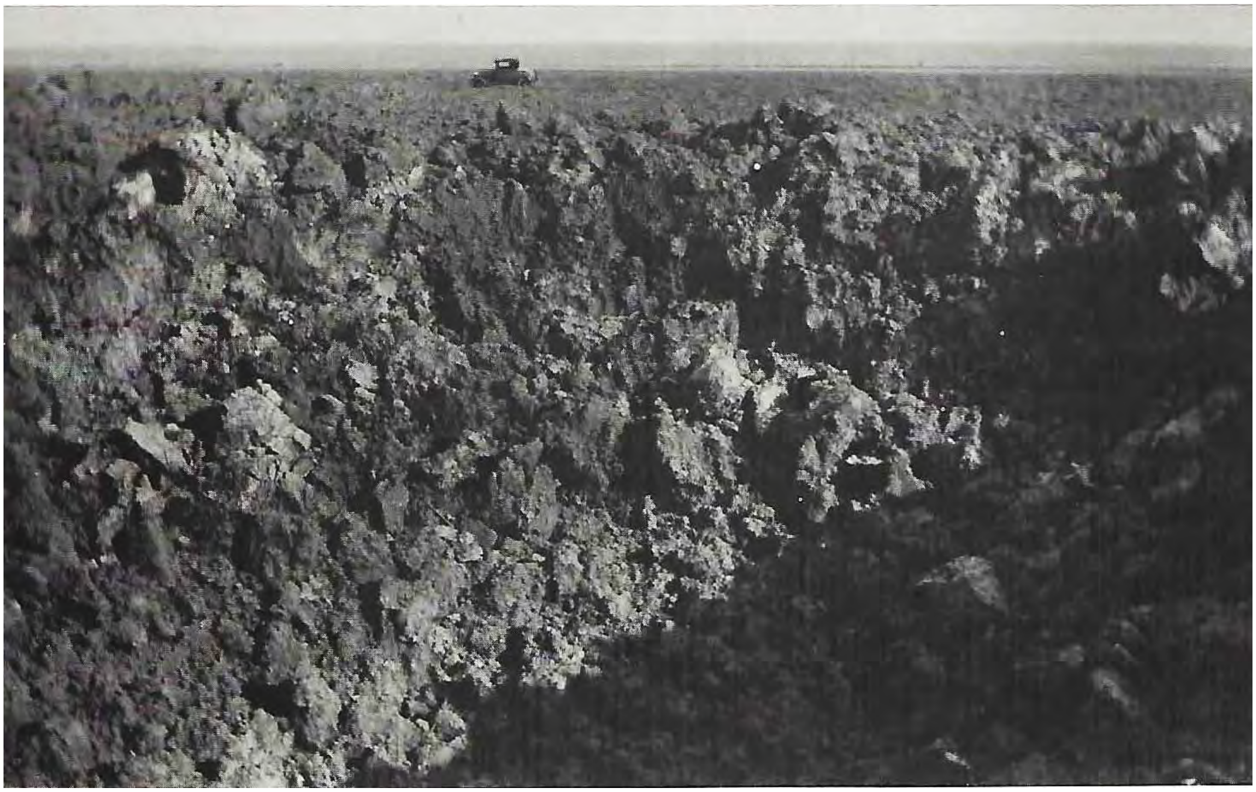
As we reached "home", as we called it, we saw a camp fire burning and Pop sitting by it raking coals under a pot of coffee! We were never as glad to see anyone in our lives!!

Pop did not know what had been in our minds, but he had been shaken by an experience of his own, and we all needed that coffee on an equal basis. It seems that Pop had underestimated the force of the explosion-to-be and was too close to the shot point when he fired it.
As was his custom, he was sitting on his box of dynamite as debris and dirt shot past him. But that wasn't half of it. As he told it, the dynamite lifted a huge cone of earth about 20 feet into the air. Ordinarily, most of it would have fallen back into its crater and nearly filled it up. But a phenomenon happened - a second explosion occurred in the air just under the cone of earth which Pop described as being several times larger than the first explosion. This second explosion scattered the cone of earth in all directions, especially upwards. The flash temporarily blinded Pop. Then big clods of earth, some as large as his Model T pickup, began to fall all around him. He grabbed his powerful flashlight and turned it upwards. The sky was just full of hunks of earth of all sizes and at different heights, but all seemed to be over his head. He jumped about, dodging them as they came down. Needless to say, we never had to warn him again about sitting too close to the shot point! And so a real thriller started our first research field job.

We puzzled for years over what caused the second explosion. Pop explained it by saying that the shot of dynamite opened up a gas pocket over a shallow gas field on the flank of the salt dome and the gas rushed out

and was ignited when it hit the hot earth. He insisted we should renew our lease and drill a gas well there. Dabney and I did not buy his explanation but had nothing better to offer.

Only 2 years ago, when reading a copy of The American Rifleman, did I discover the cause. It was the phenomenon known to experienced shooters, artillery men in the war and naval designers as the "secondary muzzle flash”. A copy of the article from The American Rifleman, for those who may be interested, is in the appendix.



The big shot-hole crater at Stratton Ridge that resulted from a 300 pound charge of dynamite.

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A Wild Experience at Hoskin's Mound

We had hoped to find a short cut to salt dome discovery by recording reflections from the crystal rock salt which we thought should make a perfect reflector. We also thought that we would get the strongest reflection by recording close to the shot point. The first thing that happened was we got so close to the shot that it knocked our instruments into the air and nearly wrecked them and us too. Then we moved back and got what we thought was the reflection to end all reflections. We cut our sensitivity down to where we got a quiet line shortly after the first shock and then came a sharp event with an amplitude of about half an inch which had a frequency of about 100 cycles per second. It was beautiful. We had figured about where to look for the reflection from the salt on the record and it was about in the right place. The best part was that we used only 5 pounds of dynamite in a deep hole and it made practically no noise. We repeated the shot several times with the same result. We moved about on the dome but always got the same "beautiful salt reflection”. We shot off of the dome and we did not get it. We were in business. But before we felt confident enough to use the method in commercial work, we felt we should try it on at least two domes.

Hoskins Mound was only 9 miles from Stratton Ridge and it had a sulphur cap so there would be a place to see if sulphur would reflect the same as salt. A local company was producing sulphur by a secret process there, pumping superheated steam down a borehole into the sulphur cap, melting the sulphur, and pumping it out as a

liquid. Other sulphur companies were sinking a shaft to the sulphur, sending men down to dig it out with pick and shovel, and lifting it out by elevators. So, their process was much cheaper and safer. They were zealously guarding their secrets lest other companies learn them and compete. Employees lived at the plant and no one was allowed to approach, even close. We were told that on more than one occasion, a trespasser had been caught and was never heard of again. Rumor was that they wound up in the fire boxes of the big boilers. We were told that the company had been accused of murder but never convicted because the bodies were never found.

Access to the dome was by a long straight gravel road from the paved highway, and the road was patrolled night and day by an armed guard.

Dabney and I decided we would outwit the guard and get a shot anyway. It is understandable why we did not want to get caught. In order to get above the sulphur, we would have to go half way to the plant on the gravel road, and of course, it would have to be done at night. We cased the place for two nights and found that the guard made his trips once every hour and at the same time both nights. We decided to make our shot at about 2 o' clock in the morning right after one of his trips. We hoped to do it without being discovered, but in case the guard started from the plant, we figured we would have time to throw our stuff in the open Model T and beat him to the pavement. We would turn our lights off just before we got there so the guard couldn’t tell which way we turned, and we then picked a hideout in the brush close to the intersection to which we would run with our lights off.

We rehearsed loading the shot and setting up the instruments in the dark until we had it down pat, and we practiced driving the Ford at its slowest pace in high gear without killing the motor. At this speed, it was extremely quiet. Near the appointed time, we parked in the brush and watched the guard make his tour. When he got back to the plant, we drove in slowly with lights off, speedo metering our distance for shot point location.

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We turned our car around and left it in the middle of the gravel road for a quick getaway. If we ran off the gravel we would be hopelessly stuck in the mud. As noiselessly as possible, we drilled our auger hole for our 1 pound of dynamite which was primed before we started. We set up our instruments on the ground, made the shot, and recorded the record.

When the shot went off, every flood light at the plant flashed on and we knew an alarm had been given. We threw our stuff into our car, jumped in, with me at the wheel, and looked back at the plant just in time to see the guard's headlights heading down the road towards us. I never drove that car any faster in my life than I did racing that guard to the paved road intersection. Everything went as planned. We turned our lights off before making our turn, then ran a few hundred yards in the darkness and turned into our hiding place. When the guard got to the paved road he hesitated, trying to figure which way we went, then turned the same way we did and passed us by at high speed. Pretty soon he came tearing back and went the other direction. Then he drove back to the plant but not for long as he soon repeated the performance. Needless to say our hearts were in our mouths for fear he would discover us, but he didn't: Then we eased out with lights off and drove very slowly until we were out of sight of the plant, then aired out for "home”.

We quickly developed our record and it was a good one. Seismic Reflections There, much to our satisfaction, was the same "beautiful salt reflection" only this time we assumed it to be from the sulphur cap. We later surreptitiously made several shots on a salt dome near Freeport, and on every shot, we got the same supposedly salt reflection and on nearby shots off of the salt, we failed to get it. We felt we would be justified in using this theory in our commercial work, but, as a backup, we still did a thorough research job using refracted waves.

Domes by the Dozen

Our first commercial job was given us by Olive Petroleum Company, a corporation owned by Van and his associates Charles G. Hooks of Houston and Dr. Alf W. Roark of Saratoga. We were asked to shoot a 20,000 acre block of timber land in Hardin County, Texas, belonging to my father and associates and leased to Van. It was known as the Olive Prospect because it surrounded the old sawmill town of Olive.

Dabney had previously done surface geology studies on the area and had reason to believe there was at least one salt dome on it. So we made a deal with Van to reimburse us for actual shooting costs and carry us for an interest in any oil found. Thus a salt dome discovery on this job would be a bonanza for our whole family.

We could hardly wait to get off a reflection shot in the spot Dabney expected a dome. We got that "beautiful salt reflection" which we thought we had proven would show up on any shot over a dome. We were thrilled to death to see it happen on that first shot. We made more shots close by and verified it. Then we started to move further away to find the edge but everywhere we shot we found another dome, we thought. We finally went so far that we figured we would have to be off of it but we got still another. Then we decided we must have a nest of salt domes.

Foolishly, instead of getting suspicious that something was wrong with our theory or instruments, we drove thirty miles to a telephone and woke Van up in the middle of the night to report that we had hit the jackpot on domes – not only did we have one but we had a whole bunch.

Next day we were still on cloud nine for we still thought we had hit the jackpot. We continued to find more domes until finally we concluded there was something rotten in Denmark - there just couldn't be that many domes and we wished we hadn't phoned Van.

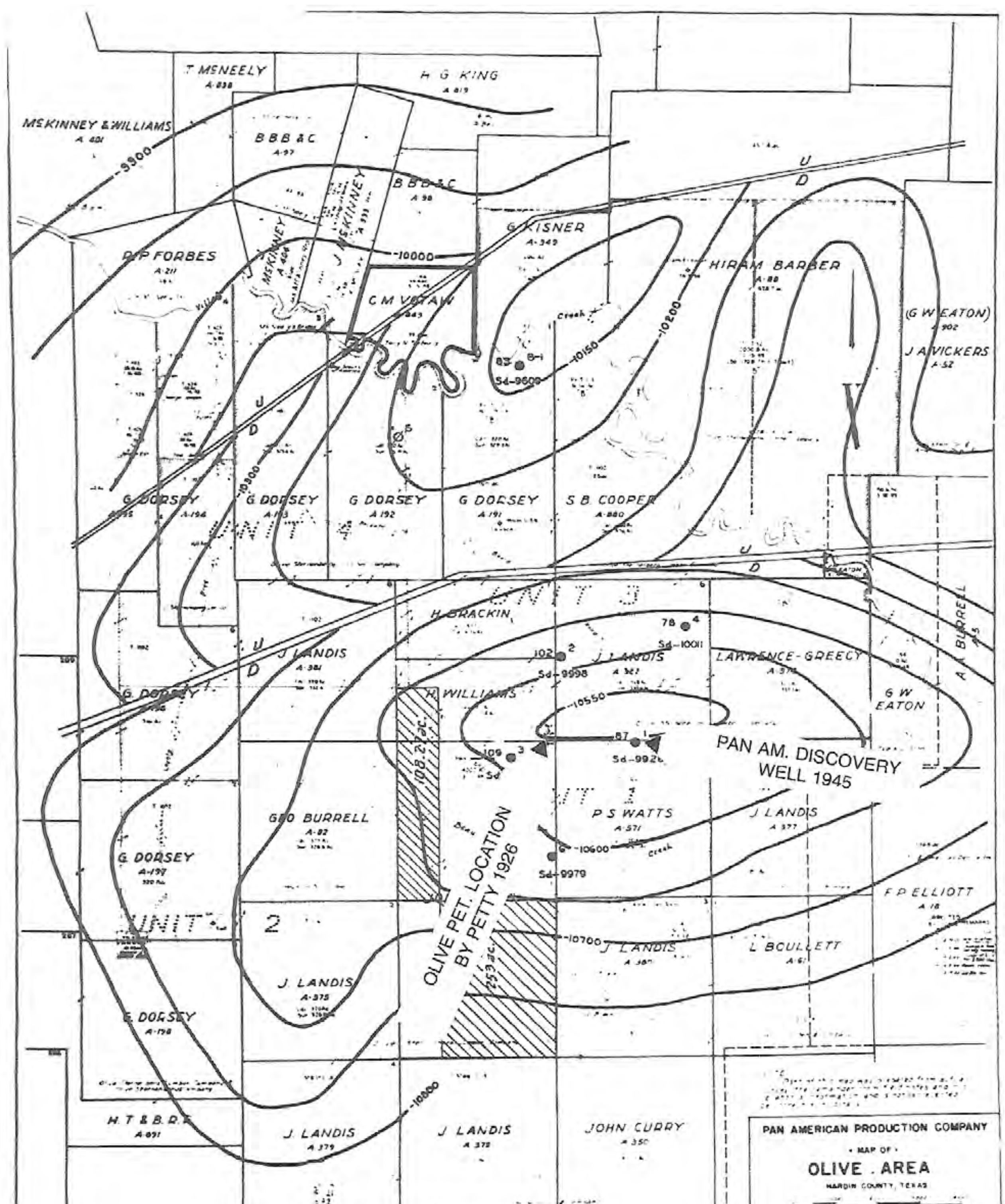
We nearly panicked when we concluded we must be wrong and we set out to find the trouble. We decided to shoot a reflection shot on two more known salt domes and then get some shots where we knew none existed. To make a long story short, we did just that and got dome records on the domes and also dome records where there were none. Now the question was what happened at Stratton Ridge where we did the same thing and consistently got dome records on Stratton Ridge, one on Hoskins Mound and several at Freeport and none when we shot where there was no dome. Our conclusion was that it must have been a coincidence and something must be wrong with our seismograph. Careful examination revealed that a lock nut had loosened on our steady mass and the shot of dynamite started it vibrating at just the time we expected a reflection to arrive from the salt. It was one of those one-chance-in-millions coincidences, and we fell for it.

Now the horrible question was, who would call Van and break the sad news? Several days had passed and we knew he had told his associates, as well as our father, of our report. We drew straws to see who would telephone and I lost. It was one of the most embarrassing moments of my whole life when I broke the news to Van. He should have shot us both!

Before the job was over, we redeemed ourselves a little bit by an accomplishment of which I am still proud. We found and mapped a geological structure favorable to the accumulation of oil under which the salt, if any, is more than 10,000 feet below the surface. We made a well location on it but warned that it was not a shallow salt dome and recommended the drilling of a deep well. We predicted that "oil field digging" would be reached at a shallow depth that is that the formations would be unusually hard compared to those around it.

Deep holes were expensive in those days and Van was unable to interest a major company in drilling a deep test. Olive Petroleum Company, on its own resources, drilled a well to a depth of 2,808 feet just to see what they would find and they did find the hard formations we had predicted. Twenty years later Pan American Production Company offset the well and drilled to 10,080 feet and got oil production. It was known as the Olive Field. We found the Olive Field by a combination of refraction waves and Rayleigh waves. The normal pattern

of Rayleigh waves changed completely on every line that crossed it. We double checked it by taking shallow cores with a 20 foot earth auger - the surface formations grew harder as we approached our subsurface high point. This was the first time in the world that a structure of that nature had been found with a seismograph.



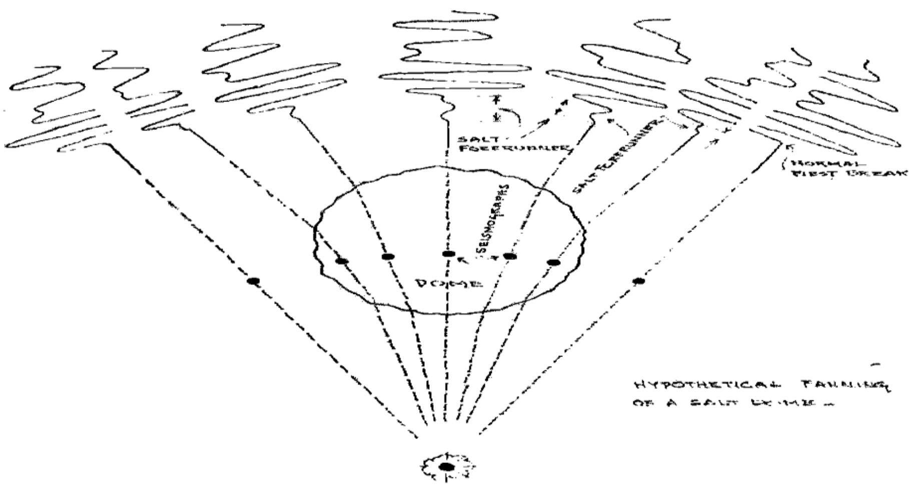
Pan American's subsurface contour map of the Olive Field, made 20 years after the-structure was found by Petty.

It Never Rains but it Pours

We made only two "temporary" mistakes during our first few years' work, and as luck would have it, both were made for the same client - Van and his associates. At that, we were lucky that we didn't make more for we were using new theories of our own in our short cut method of searching for shallow salt domes. Note that I call the two mistakes "temporary" because we discovered them while the jobs were still in progress and really the mistakes were in raising false hopes in our clients, which could have been avoided had we kept our mouths shut until the jobs were finished and the reports done.

During our experimental shooting near known shallow salt domes, we observed, on our record, what we called a "salt forerunner"- a low amplitude, high speed wave. By taking a path through part of a salt dome (which has a higher velocity than the surrounding material), the forerunner got to the seismograph before the normal high amplitude wave through the clays and sands that surrounded it. The interval of time between the arrival of the forerunner and arrival of the normal wave represented the amount of time that the forerunner saved by taking its path through the salt. This offered a quick clue to the nearby presence of a salt dome because the difference in the amplitudes of the two waves was very striking. The difference could be observed at a glance without any computations. In other words, you did not need to know the travel times involved or the exact distance from shot to seismograph. It was just the time represented by the length of that forerunner that was important. That was the clue to the presence of a salt dome in the area. Its exact position could be determined by "cross-fanning" the area with multiple lines from two different shot points. When you got a forerunner, the wave had gone partly through salt; when the forerunner was absent, the wave had missed the salt. Simple as that.

The above is the situation in a large part of the lower Gulf Coast of Texas and Louisiana where Mother Nature laid down massive beds of clays and shales with relatively thin beds of lower velocity sands interspersed in the denser formations.



Hypothetical fanning of a salt dome. Travel time of seismic waves through salt is less than time through surrounding material.

So long as that situation held, this was a great tool and enabled us to explore hundreds of thousands of acres at a fraction of the cost and time that it would have taken had we operated like other companies – measuring the lengths of the shot lines and recording shot times and plotting them on graph paper.

However, we discovered that Mother Nature is not always consistent. Occasionally, especially further back from the coast line, she also laid down massive beds of sand at relatively shallow depths which upsets the apple cart. When a thick bed of sand underlies a denser bed of clay or shale, it can cast a seismic shadow so to speak. A seismograph set up in that shadowed area may record a wave pattern that looks just like a salt dome record in a more normal area. What looks like the high speed salt forerunner is actually the normal clay or shale wave whose amplitude has been drastically reduced because of the seismic shadow.

One such area, and the first we ran into, is around the town of Addicks just west of Houston. We were using our short cut system and our seismograph happened to be in the seismic shadow zone. We recorded the pattern I have just described. Again, just as we had done on our first job for Van, we excitedly phoned him that there was a dome close by, but we did not know exactly where and not to take any leases until we pinned it down by fan shooting

However, as we fanned, we never could get a record without the forerunner. After several days and lots of "blood, sweat and tears" it finally dawned on us that Mother Nature had thrown us a curve. Again we went through the trauma of phoning Van and we adopted another policy: don t ever tell the client anything, if you can help it, until the job is over.

Had it not been for our good friend, Wallace Pratt of the Humble Company, we would have been put in the Houston jail on a felony charge of using such large charges of dynamite so close to the center of Houston that our seismic waves were endangering the Houston City Hall . It seems that our shots were rattling the windows in City Hall, and the police department, after an investigation, decided it was a Humble crew doing the work. The Chief of Police notified Humble that if they did not stop it immediately, the entire crew would be jailed and the Humble Company would be sued. Mr. Pratt knew it was his old friends, the "Petty boys," who were doing the shooting, and so he phoned me at the Rice Hotel and suggested we reduce the size of our charges lest we all wind up in jail. Incidentally, he said we were rattling the windows in the Humble Building, too!

Actually, the damage was not from the seismic waves but from sound waves through the air. We were using air waves to measure our di stances and had been hanging a 50 pound box of dynamite in a tree and fi ring it with each ground shot. We continued to use the same size ground charges, but quit shooting any air shots, and the window rattling ceased. Never a dull moment in doodlebugging!

Two segments of refraction records: one normal and the other showing a salt forerunner. Records made for Humble at McFaddin Beach in 1930.

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Asleep at the Switch

There was one shot on the Olive Prospect that I will never forget, nor will Edwina. It was to test an area called Iodoform Hill, so called because there was always the odor of iodoform there. Dabney suspected that the odor must come from a gas seep close by and that the hill (in that flat country, anything with an elevation of a

few feet is called a hill) might have been caused by a salt dome. Ask any old timer in the area what caused the smell and he would tell you it was an oil field. Dabney thought that might be true for he could think of no better explanation but it did not have the odor of petroleum which made it a mystery. Anyway, Dabney had long considered it a good bet for a salt dome and could hardly wait to shoot a line across it.

The area where we would need to set up our seismograph was heavily wooded and since trees cause ground unrest when windy we needed to find a clearing in which to operate. The day before the shot we scouted the area and found just the spot, a clearing about 100 yards in diameter, and we blazed a trail to it so we could find our way back in the dark. Then we located a shot point at just the right distance, putting Iodoform Hill between the two.

We were behind schedule with our shooting and so decided to make this a big shot so there would be no chance of our having to repeat it. We decided on 300 pounds, which was lots of dynamite, especially since our funds were running low. Pop Reichert was to be shooter and Dabney his assistant. I would be the observer and Edwina was my assistant.

As we parted that night, we synchronized our watches and agreed on the exact second on which the shot would be fired, or, in case of emergency, it would be fired exactly fifteen minutes later.

As Edwina and I drove up on that clearing that night we were disappointed to find it filled with cattle because a cow stomping around is worse than wind blowing a tree. However, we had no choice but to set up there as we had no way to communicate with the shooter.

First thing we did was to drive the cattle away by throwing sticks and yelling but they were not very happy about leaving as there are less mosquitoes in a clearing than in the woods. There was a big bull with them and he was mad, which added spice to the situation. We finally got them moved but they came right back so we decided to go ahead and make our set up with the cows around us.

When we finally had our instruments ready, we decided to make a trial run. We drove the cattle a good 200 yards and then hurried back to see how long before they got back close enough to ruin our recording. As we sat quietly and watched our recorder we were amazed to see someone's footsteps approaching.

Now if you want something spooky, just try sitting inside of a little tent way back in the deep woods on the fringe of The Big Thicket in the middle of the night and watch (on the seismograph) some unknown person walking up on you, not knowing from what direction he was coming, who he was or what he wanted. We stepped out of the tent and looked and listened but could see no one. Then we went back to our seismograph and saw the footsteps getting closer and closer.

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We could tell because the vibrations got larger and larger - and we had long ago learned to distinguish between the footsteps of people, cattle, hogs, or small varmints. Whoever it was would walk for a few moments, then stop as if to listen or watch. Then he started circling us. So, we knew whoever it was watching us.

Pretty soon the cattle came back and drowned everything out. We drove them away again and again. The bull posed a problem that had to be handled gently but a big yellow cow with extra-long horns was the most troublesome of all. I could drive her 200 yards and she would follow me right back. As I walked I would watch for our mysterious visitor but never could see him. He stayed close by, however, as we could tell by his occasional movements.

Finally the time for the shot approached and a decision was in order. Obviously one of us would have to chase the cattle away and stay with them to prevent their return and the other would have to stay in the tent and start the camera a few seconds before the shot was fired. Edwina did not relish the idea of chasing cows (and a bull) through the woods in the dark with an unknown prowler nearby, and yet it would be just about as dangerous for her to stay in that tent by herself with me 200 yards away in the woods. She was not so worried about that since she had my Colt .45 and was a good shot. What worried her was the responsibility of recording that big shot of dynamite.

We decided it would be best for her to be the observer, and we rehearsed the procedure for quite some time. It went like this: keep an eye on the watch; start the camera seconds before the shot was due; let the camera run until the sound of the shot had been recorded; then stop it.
Simple enough but she was afraid she might panic when the time came. It was a chance we would have to take.

So, 5 minutes before the shot, we wished each other good luck, and I started out to drive the cattle. It was not easy, for by this time, they had decided I was harmless, and they just wouldn't move until I got a long pole and whacked one or two across the back. The yellow cow decided she would rather fight than move but finally gave it up and all went well.

On the appointed second, the big shot went off, and its roar through the quiet night sent the cattle scattering. I ran back to the tent on the double, so anxious to know if we had found a dome. I had explained to Edwina how she could tell one by watching for the small salt forerunner without waiting to develop the record.

So- all out of breath I rushed up to the tent and yelled "did we get a dome? Did we get a dome?" Her reply: "I don't know. I fell asleep!"

Although we made local inquiry, we were never able to learn anything about the stalker. We assumed he fled with the cattle.

Snakes in Chacahoula Swamp

The snakiest place I ever worked was Chacahoula Swamp in LaFourche and Terrebonne Parishes, Louisiana, reputedly the worst swamp in the State. By standing still in one spot for 3 minutes, I counted thirty-two cottonmouth moccasins lying on the water or in the bushes and trees.

Colonel E. F. Simms, an independent oil man, had leases on several hundred acres right in the middle of that swamp and had reason to believe there was a shallow salt dome on it. The swamp was supposed to have been shot by several major oil companies with negative results, but actually only the edges had been shot because the swamp was so bad. The Colonel's lease rentals were due in only a few days, and unless he could get some encouraging evidence of a dome, he would let his leases expire. The lease had an enormous gas seep on it about which he told
Van. He also told Van that we would get an overriding royalty if we would shoot it before his deadline.

Van made the deal and gave us a map showing the location of the lease and the gas seep, and we started operations immediately. There were no roads in the swamp, but there were bayous winding around in it which we could use for the transportation of our instruments. A paved road bordered the swamp on one side and gravel

roads circled it. We figured we could locate our shot points within a mile of the gravel roads, set up our instruments in the interior, and shoot a line across the salt, if any.

As a starter, Dabney and I decided to scout out the swamp on foot and to swim the bayous if they got in our way. Dabney was particularly anxious to see the gas seep. A walk such as this should have been started early of a morning for the swamp was formidable and the water level extra high due to incessant, heavy rains, but preparations for the walk took up the whole morning.

We drove to a spot on the paved road closest to the lease and scaled the distance from our starting point to the lease to be 4 miles. We left our Model T parked on the road and started walking and wading in the right direction at exactly 1 o'clock. We wore tennis slippers for fast walking, wading, climbing logs and for easier swimming. We each carried candy bars, a flash light, note book, compass, and a machete. It was a never-to-be forgotten experience. We walked, waded, and climbed over logs for four hours. We did not find the gas seep but we learned the swamp.

One hour before darkness, we decided we had better make tracks and get out of there or the mosquitoes would be unbearable.

Dabney decided to climb a cypress tree to see if he could map a route back to avoid the deep bayous. That was when I counted the thirty-two cottonmouth moccasins and lots of them were up that tree. First we had to de-snake it, which we did by beating on the trunk and throwing sticks up at the snakes. It rained snakes for a minute. The climb did us no good. "Water in all directions" was Dabney's report. We figured it best to walk in a straight line towards the car and swim any deep water in our way.

Luck was with us in getting out. We ran when it was dry enough or walked fallen logs lying in our direction of

Don't you believe that that rule applies to cottonmouth moccasins. They are aggressive and will come at you with their big white mouths open nearly every-time -at least they do in those Louisiana swamps. When one got too close we would whack him in two with our machete. We had kept good track of our wanderings and hit the paved road just at dusk about a quarter of a mile from our car. We were completely exhausted but before we could rest we had to de-leech each other. Louisiana swamps are full of leeches and we had them hanging on our skin from the waist down, and did they hurt! We hoped we would never have another experience like that. Really Dabney and I were lucky to get out of that experience with nothing more than mosquito bites and skinned legs. The swamp, like most Louisiana swamps in those days, was infested with alligators. Now, alligators will not ordinarily attack humans and so the danger is minimal unless you step into an alligator's nest when mama is home with babies. Then you can lose a leg or a life. On more than one occasion while wading in waist deep water we would suddenly go over our heads into an alligator's nest.

While we were scouting the swamp for an observation point, our party chief, Smokey Allen, and our shooter, Pop Reichert, were scouting another part of the swamp for a suitable shot point location. The next day while Smokey and Pop were moving the dynamite to the shot point,
Dabney and I, with a Cajun, four Negro helpers, and two pirogues, were busy moving our instruments to the observation point.

Pirogues, canoe-like boats, were used to transport crew and equipment in the Louisiana swamps.

By nightfall Smokey and Pop started loading dynamite while Dabney and I started setting up our seismic equipment. There was no dry land around; so we had to set our light proof observation tent over the water on logs and a few boards we had brought along.
We set our seismograph on a cypress stump. We had never tried this before and were not sure it would work but it did.

It was a memorable night for everyone on the crew, even for the Negro helpers. Snakes were everywhere and our lanterns left something to be desired. We encountered serious trouble trying to establish radio communication between the observation point and the shot point due to the big trees in the swamp between us but finally, shortly after daybreak, we made the shot.

I will never forget that first shot. By this time, we could recognize a salt dome record by watching the shadow of the string even before we developed the record. This first record was the prettiest salt dome record we had ever seen. We shook hands and congratulated each other and then verified our visual interpretation by developing the record.

While Dabney and I were sure we had a salt dome, we felt another shot from a different direction should be made to confirm it; so another 24 hours were spent in a repeat performance which made over two days and nights with no rest or sleep for anyone on the crew except for the
Cajun and Negroes.

So- in just 2 days we had located a salt dome that had been missed by several major oil companies because their seismograph crews did not choose to penetrate Chacahoula Swamp!

Incidentally, just this year Smokey (Thomas L.) Allen published his autobiography which is titled "The Twentieth Century as it Unfolded for Me." It seems he kept a diary of his activities while working for the Petty Company and I quote verbatim part of the entry he made concerning this same episode:

We made our temporary headquarters at Houma and spent all the daylight hours of the first day to move the explosives to a selected point in the swamp, where we sank holes to a depth of twenty feet with six inch post hole diggers and loaded the explosives in the hole. There is a memory from the first day that I often recall. The landowner of the point selected for the shot point was apprehensive that the explosion might be detrimental to his wife, who was expecting their fourteenth child shortly.

In Chacahoula Swamp, D.E. Petty washes the record that discovered the salt dome. (Note seismograph on stump.)
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O.S. Petty resting beside lightproof observation tent in Chacahoula Swamp.

We assured him that the explosion would hardly be noticed and he agreed to help us move in the explosives and load the holes. One of his black neighbors joined us also, and in the course of the conversation, it was mentioned that Mr. Thibodeaux was expecting number fourteen soon. The black man expressed his admiration with these approximate words, 'Boss, you sho is a wah
hoss. To make number fourteen at your age, you sho is a wah hoss.· "

Thomas L. (Smokey) Allen's book would be of interest to anyone interested in more details about the early history of the Petty Company or the documentation of any statements made on the descriptive cards accompanying

the instruments on display in the" Museum." A copy of the book has been placed in one of the cabinets, available for loan to any interested party.

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Cajun Gourmet - A Snapping Turtle

A sidelight on our trip up the bayou:

A pirogue is a long, narrow canoe-like boat usually made from a hollowed out cypress tree but where heavy loads are to be carried it is made a little wider and lots longer by use of boards. The pirogue is a standard form of transportation in the Louisiana swamps and bayous. Needless to say, it is very unstable. The small ones are generally propelled by a man standing in the stern pushing against the bottom with a long pole, but the larger ones generally have a man with a pole in the bow also. They "pole" instead of "paddle”. Dabney and I each had a pirogue with a Negro in each end with a long pole. My pirogue was the smaller and I carried our more delicate instruments while Dabney carried the bulkier equipment and two extra men, one being the Cajun contractor boss.

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The pirogue is a noiseless craft as it glides along the bayous but not so the crew. When you get five Negroes and a Cajun together, the yelling and laughing is unbelievable but amusing. As we glided under the cypress trees, all noise suddenly stopped and my men put fingers to their lips signaling for me to be quiet. They were pointing at something ahead but I had no idea what they saw. Then my boatmen pushed my pirogue close to the bank and moved silently and slowly ahead. The man in the bow boated his pole and crouched down ready to do something but I couldn't see a thing. Suddenly he leaned over the side, thrusting his arm in the water nearly up to his shoulder and grabbed something and started pulling on it. He pulled and wrestled something and very nearly turned the pirogue over. One side dipped clear under and lots of water came
in. I thought our instruments were gone. Fortunately our instruments were setting on boards off of the bottom so they were not ruined. I yelled for them to stop it but they paid me no mind. All of the Negroes and the Cajun were yelling and laughing at the same time. It was quite a to-do and more than once I kissed our instruments goodbye. Finally this Negro came up with an enormous snapping turtle, holding him by the tail while the turtle twisted and cavorted trying to shake loose or get a bite at his captor with his big ugly head. Then he flopped the turtle on the bottom of the pirogue on his back and turned loose of his tail.

Now a snapping, or logger head, turtle is something else again. This one weighed nearly 30 pounds. He had a long, rough, black tail which he whipped about like an alligator and his head was as big as two doubled-up fists. They have jaws as of steel and can take a finger off or a hunk out of your hand with one snap. Once he gets a hold on you he won't turn loose "till sundown" the Cajuns say. On their backs, they are helpless as they can't quite turn themselves over - but they surely do try. His head, tail, and feet were fanning the air and pounding the pirogue for all it was worth. The whole performance would have been comical - it was like a vaudeville act - except that we were crowded for time.

We had a long way to walk and carry the instruments after we got to the head of the bayou. Dabney and I tried to hurry them up but it was hopeless. They were enjoying the excitement immensely. Finally more time was lost while they showed us how big a hunk that turtle could take off the end of a pole with one snap. And I had to put up with that flopping turtle all the way to the head of the bayou. They dressed the meat out during the day as Dabney and I did our thing. The Cajuns consider a snapping turtle to be one of their finest delicacies and they considered this a supreme specimen. I'll bet they had quite a feast and celebration that night for if there is anything Cajuns excel in, it is cooking their food and drinking their homemade wine.

So - Colonel Simms nearly lost a salt dome and we nearly lost our only set of instruments all for a snapping turtle!

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Main Street in Thibodeaux, Louisiana, photographed by Pop Reichart because it had the "first one-way street sign I had ever seen." Dabney Petty was later arrested in this town for speeding. He was traveling at the reckless speed of 15 mph speed limit was 10 mph.

1926. Dabney relaxing on log between

Chacahoula shots.

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A Reminder

I am about to tell you of an event that happened at Skull Creek, but lest you get a wrong impression about the ethics involved, I must remind you what geophysical exploration was like in those early days. Ethics were always our strong point and never did we stray from the straight and narrow path. The years 1924 to 1927 saw the wildest competition between oil companies in the history of the Gulf Coast. Up until that time, the exploration for shallow salt domes was in low gear. Drilling was based mostly on surface indications, such as oil or gas seeps, suspicious surface elevations, hunches, and random drilling. Suddenly, almost overnight, there appeared a way to find shallow domes fast and with certainty. Mintrop seismic crews were the answer. But only a few major oil companies had them. The others could not get them because they were not available.

So - other major oil companies and independents had to shift for themselves in any way they could. They hired scouts in great numbers to watch the crews for any unusual activity that might mean they suspected a dome might exist. If, for example, a crew should shoot a cross fan at an angle to one they had already made, that was fatal. The first scout to learn that would phone his company and within hours they might have lease men trying to lease the area where the fans crossed. You had just better not go back to a shot point a second time even though you missed the first shot. Scouts were hired to scout the scouts.

Every seismic crew had a number of scouts attached to it who followed it constantly, day, or night. The crews tried every way to shake them, such as changing their working hours, starting out to work in a different direction from where they were working and looping back , putting out false rumors, etc., etc., and the scouts tried just as hard to outwit them. It was every man for himself. Of course there was lots of bribery going on too. Sometimes the company that found a dome got less acreage than their competitors. So - anything went in those days. You had just better be smart enough to outwit the other fellow.

Skull Creek

The name is eerie and so was our experience. Van heard a rumor that a major oil company had found a dome at a certain place on Skull Creek in Colorado County; Texas, and was waiting for things to cool off before taking leases. Could Dabney and I check it secretly without any permits? If we could verify it, he would take some leases and carry us for an interest. We accepted. This would not be our first secret job as we had done it often before and were well prepared and equipped. We had black gloves, long black rain coats, and black rain hats that buttoned around our faces and necks leaving only our eyes showing. Our Model T, our instruments, and our tools were all black and our flashlights had black hoods over the lenses. Give us a good dark night on a country road and a drizzling rain and we were at home.

The necessity for secrecy was because if the major oil company learned we were working there they would immediately lease it up if it was a dome. Then too, if we were caught with dynamite and a seismograph on a country road at night with no shooting permits, it would be hard to explain to the sheriff. We had nearly been caught a few nights before when at two o'clock in the morning a boy and girl rode right by us on bicycles. We had a habit of stopping work about every two minutes and listening for voices, footsteps or a car, but the silent bikes got there before we had a chance 10 hide. We just froze, and they rode right past without seeing us.

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Pop wasn't with us this night. Dabney's and my job was to drill a 2 inch diameter hole 18 feet deep and load a 10 pound primed charge of dynamite in the bottom. Then, the next night, we would return and shoot it.

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We were being extremely careful in our work for if you find a dome it could be worth a fortune, and you don't want to make any mistakes. First, we selected a spot where we could leave the shot hole until the next day without it being discovered. We chose some carpet grass about twenty feet from a gravel road behind some bushes. Our car was well hidden. We spread a piece of canvas on the grass so our shoes wouldn't scar it up. In the middle

of the canvas was a hole through which we drilled with our earth auger. We dropped the clay cuttings on the canvas and hid them when we were through. Before starting to drill we cut out a plug of carpet grass, roots, and all, to be replaced over the hole when we left. And we always referenced the hole in to nearby trees so that we could be sure and find it the next night.

Everything went off perfectly. We stopped and listened frequently and never heard a sound except the crickets. No vehicle or people passed on the road. After loading the charge we rolled the few feet of copper cap wires into a ball and stuffed them in the hole about 6 inches below the surface. Then we replaced the plug of carpet grass over the hole, rolled up our canvas with the clay cuttings in it, and admired our handi-work. It was perfect - not a foot print to be seen. We cut a twig of brush and stuck it in the ground one foot from the hole so we could find it easily in the dark next night. It looked like it was growing there. The same kind of brush was growing all around. About two o'clock the next morning we went back to do the shooting. The twig was gone. When we removed the carelessly replaced. We reached in for the wires and they were not where we left them but had been unrolled and were deeper in the hole. Our cap tester indicated an open circuit, meaning either the charge had been fired or a wire broken or cut. We pulled on the wires and they came out easily. The business ends showed that the shot had been fired. This was truly a mystery and one that we could never figure out. Who fired the shot and why? It could hardly have been a child because it took a battery or blasting machine to do it. Whoever did it must have known there was dynamite around the cap. I'd think he would have been afraid the shot might have blown out and kill him. A 10 pound charge could not blowout at that depth, but how did he know how much we put in unless he watched us? Why wouldn't he have said something then? Or put the sheriff on us?

That was to be our last shot on the Skull Creek prospect. We had already proven to our own satisfaction that no dome existed there and we decided to let well enough alone. The next day Pop went into Columbus for some supplies and picked up the rumor that something strange was going on at the camp ground at Borden (where we were camping). Seems there were some men camping there who were gone all night and came back and slept in the day time. The sheriff had talked to the farmers and the men were not working for any of them nor could he find any place else in the county where they were working. There had been some bank robberies recently in that part of Texas. The sheriff was going to arrest these men on suspicion of being the bank robbers. We left.

But I am still wondering, after 50 years, what happened to that last shot at Skull Creek.

(22)

What Is A Geophysicist?

Geophysics was a word very seldom heard. No one knew its meaning, I remember once in 1928 we were staying at the old Monteleone Hotel in New Orleans and shooting a job in the marshes. I was Party Chief and Charlie Hightower was my assistant. I had Edwina with me and Charlie had his wife, Margaret, with him. One day at dinner; our wives announced that they had a problem. Their problem was, they said, that in meeting strangers one of the first questions that was asked them was "What do your husbands do?" Their proud answer was "They are geophysicists." That fell flat. A puzzled look would come over the faces of the strangers. The next question was usually "Yes, but what do they do?" Then the girls would try to explain that we buried charges of dynamite in the ground, set up seismographs a few miles away, shot the dynamite, and recorded the earth waves, and then, from a study of the records, try to find an oil field. That was an involved answer and generally led to still more questions. What Edwina and Margaret wanted to know was what could they call us that people would understand? They had tried "seismologists" and that was almost as bad, as the people's next question was generally "What university do they work for?" Charlie and I had a brief discussion and suggested they just say we were engineers. Next day they tried that out and right off their new acquaintances asked "What railroad do they work for?"!

Our wives had a rough time on that job. We were shooting a large area about 20 miles south of New Orleans near the town of Lafitte; named for the pirate Jean Lafitte who chose this as his hideout because it could

be reached only by water and, besides, the mosquitoes were so terrible they would keep visitors away. The area we were exploring was about half covered by shallow lakes and the rest was marsh, perfect mosquito country. We did our work at night when the ground was quietest and slept during the days. That left no time for entertaining our wives. They jokingly threatened to quit us and marry non-geophysicists.

We added to our wives' discontent by telling them what we glimpsed of the night life in New Orleans as we came back down Bourbon Street from the field about 4:30 every morning. One night they announced they were going to the field with us and see the sights on Bourbon Street for themselves. Charlie and I took a dim view of this for the mosquitoes were just as bad as they were in the days of Jean Lafitte. The minute the sun went down, they arose in dense clouds from the marshes, - really I had never seen anything like it in my life. The mosquitoes in Chacahoula swamp were mild compared to these. We told our wives about this but they would not believe it - said we just did not want to be bothered with them. We explained that once we started shooting, we could not stop as there was no communication with the shooter - the shots were being made every hour on the hour and as always it was a hurry-up job. We just could not afford to miss them by driving wives back to town. They said they were used to mosquitoes - hadn't Edwina been my helper in the big thicket at night?

There were no in sect sprays in those days before DDT was invented. Sweet Dreams was the accepted repellant, but all it had going for it was a terrible smell to people. The mosquitoes around Lafitte did not seem to mind – they would lick it off your skin as if whetting their appetites. They were he-man mosquitoes, not pantywaists. The natives told us they had actually seen cattle killed by them.

We told our wives all of this but they brushed it aside. They begged us to take them and promised to be good. We relented. *22*

They loved the scenery on the drive to the field. The bayous were covered with water hyacinths and were a solid mass of blue. Sunset over the lakes was out of this world. Then, with sunset, came the mosquitoes. Edwina and Margaret could hardly believe it. They ran for the car and closed all of the windows, but it was worse inside than out as the car was full of mosquitoes and dreadfully hot, and Sweet Dreams was not perfume. So out they came again and tried walking fast but the mosquitoes flew faster. The most amusing (or was it pitiful?) thing that happened that night was to watch the girls wrap their legs with newspapers and tie them around with string. They worked long and hard at it only to discover that the mosquitoes got under the newspapers and really had a ball. Needless to say they never asked to go to the field with us again!

Braving the mosquitoes paid off. We found an oil field. We were shooting for C. A. Kelly, an independent oil man in Houston. We reported the discovery of a deep seated salt dome on the basis of which Kelly turned his prospect to Humble Oil & Refining Company. Humble shot it, couldn't find anything of interest and asked to see our seismic records. They were amazed at the accuracy of our seismic system. They drilled a well on our location and found an oil field.

This gave Humble great confidence in our work. They had a prospect offshore McFadden Beach near Port Arthur, Texas, where their gravity crew had reported a salt dome but their seismic crews could find nothing and their leases were about to expire. They asked us to see if we could verify their gravity discovery. To make a long story short, we mapped a reasonably shallow salt dome just offshore and Humble bought our crew - lock, stock and barrel - instruments, trucks and personnel and the right to operate under our patents - and sent this crew to hunt anticlines in West Texas.

Before buying the crew, Mr. Wallace Pratt, vice president of exploration for Humble, asked his geophysical department for their appraisal of our instruments. Back came the report. They are a typical example of the peculiar paths the human mind will take if allowed to run wild. Thank goodness Mr. Pratt did not agree. The sale of this crew was a blessing to Petty because reflection shooting was replacing refraction shooting for

general use and our instruments would soon have been obsolete and we had no reflection instruments. Humble had so much confidence in Petty by this time that they agreed to pay for our reflection research for the right to copy anything we might invent and to operate under any patents we might obtain and, needless to say, they reorganized their geophysical department!

While shooting near Thibodeaux, La., we discovered a gas seep that led to the shooting and discovery of the LaFourche Crossing Field. We took a picture of the seep and when the film was developed, a mysterious "hood" appeared just over the seep. We did not see it when we took the picture and it was not faked. To us, it looked supernatural- sort of spooky. We always wondered what caused it.

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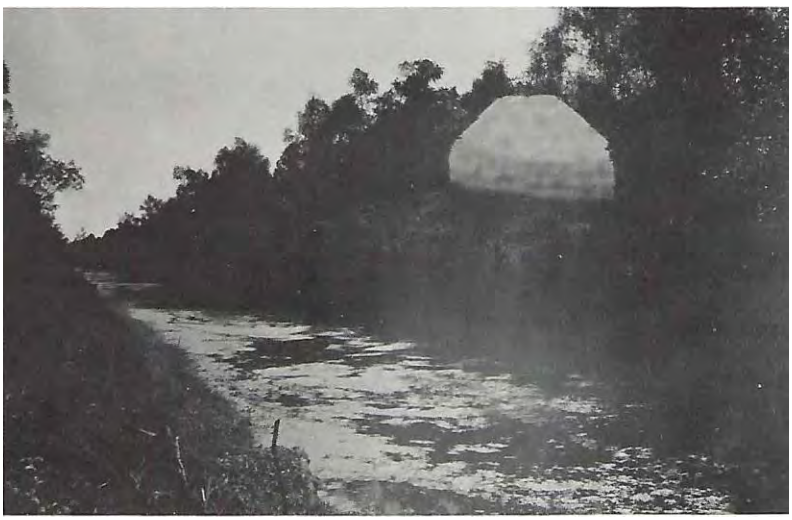

Gas seep near Thibodeaux, Louisiana. The white "hood" appearing over the water was not visible, but in the photograph, it is clearly visible directly over the gas seep.

Drilling Through the Telephone Cable

I recall the time one of our crews drilled right through the middle of the long-distance lead-covered trunk cable carrying 400 circuits from Oklahoma to Texas. That was an embarrassing situation since the telephone company had visited our crew the day before and given them a detailed map of the line location and warned them to keep well away. It was quite a coincidence to set up a drill truck and drill a hole smack through the middle of a 4 inch diameter cable. The worst part was that a compressed air signal gave the telephone company the exact location of the break and the emergency squad came driving up on the drill with the drill stem still rotating through the middle of the cable. The party chief phoned me and I nearly flipped when I tried to calculate the damages we would have to pay. Four hundred long-distance calls from no telling where to Texas for maybe half a day and that was some forty years ago when long distance calls were sky high. The crew was working for Sinclair, and when I called Fred
Bush in Tulsa, his only comment was "Never a dull moment in geophysical work”. Ma Bell did right by us though. They rerouted their calls through other lines, some going from New York to Texas via California for example, and charged us only for the cost of repairing the cable. Believe me, that was a relief.

A Different Breed

Oil men are different from any other people in the world - an entirely different breed of cats. Of course there are always a few rotten apples in every barrel, but as a whole, oil men can be absolutely depended on to keep their word. Make a deal with one and a handshake (even over the telephone) is as good as a written contract. Take our deal on shooting the Charenton prospect as an example. I was spending the night at a hotel in McAllister, Oklahoma, on my way to visit a field crew. My phone rang and it was Perry Scranton, an independent oil operator in Houston and an old client of ours. He wanted a seismograph crew for a few days' work. I told him I was terribly sorry, but every crew we had was under contract and hard at work. He would not take "no" for an answer. Said he had figured out where there was an oil field near Charenton, Louisiana, and it would take a seismic crew three or four days to prove or disprove his theory. If I could get a crew for him, some way, and charge him actual cost, he would split whatever he made out of it. I told him we not only had no crew, but we were short of cash and why didn't he get someone else to do this job for him.

He said a competitor of ours had just finished shooting it and condemned it, and he believed we could find it. Said if I would borrow a crew from one of my clients and loan it to him, he would get Harry Hanszen, another independent and friend of his, to pay the actual expenses. Harry would split with him and he would split his half with us. I said I'd see what I could do the next day and get back to him.

Next day I did some telephoning and arranged to borrow a crew for three days from a job not too far from Charenton and called Perry and told him it was a deal. That three days' work verified Perry's theory, and he started at once to getting a farm-out from the oil company owning the leases, which was easy to do since their prospect had just been condemned. To make a long story short, Perry got his farm-out, got a crew from us as soon as we could supply it, and we spent several months shooting it, Mr. Hanszen paying actual costs. We not only found one field, but we found two. It was several years before Perry was able to get a well drilled. All of this time we did not have the scratch of a pen confirming our deal - just that one telephone call. We did not worry about having nothing in writing - at least I didn't although our controller did. When at long last the field was brought in and oil was produced, we started getting our monthly royalty checks. It turned out to be the biggest oil field in Louisiana for years. Still no written contract. That went on for at least ten years, Mr. Hanszen giving Perry half of his take and Perry, in tum, giving us half of his. Finally a death in the family made it necessary, for estate tax purposes, to get legal assignments and they came through exactly as agreed upon in that telephone conversation so long ago. And this was not an isolated case. You just can't beat the handshake of an oil man!

The Shadow of Luck

Some forty odd years ago, Bill Kane, a mining engineer from Mexico, worked up a deal between Petty and the Mexican government whereby we would furnish several seismograph crews with the exclusive right to hunt oil fields in Mexico, and the government would pay actual costs and carry us (Bill and Petty) for a royalty in any oil found.

It was a fabulous deal. Bill worked on it for over a year and had the agreement all drawn up. It was on my desk for signature. The proper official in the mineral department in Mexico was to sign it right after I did. The profits would have been fantastic. The very day I was to sign the contract, I picked up the morning paper and big black headlines told of the decree the President of Mexico had just signed expropriating all foreign oil properties. That ended that, and a whole year of Bill's negotiations, as well as his anticipated millions of dollars, went down the drain. He said his shadow of luck wasn't quite good enough. You see, Bill has a theory that every person has a shadow of luck that follows him around just like his regular shadow and never changes throughout life. He was philosophical about the disappointment - said it was in keeping with his shadow.

My shadow of luck has always been real good, although at times, it has seemed poor. Like the time way back in 1928 when Olive Petroleum Company offered us two prospects to shoot for an interest. One was known as the Dr. Collier Prospect and the other as the Fannen Prospect. Both had good gas seeps on them and looked

like sure-fire shallow salt domes. Dabney and I chose to shoot the Dr. Collier Prospect and found nothing. Another company shot the Fannen Prospect and found the Fannett salt dome and oil field. Our shadow of luck wasn't up to snuff.

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Yet, looking back over my life my shadow has been very, very good. Suppose one of those big clods of earth had fallen on Pop and his box of dynamite - our company would have been wiped out. Suppose I could not have managed to borrow a seismic crew for Perry Scranton's use at Charenton - we would have missed an oil field. Suppose we had been snake bitten in Chacahoula Swamp, or stepped into an alligator nest with mama in it. Looking back over my life, I can see so very many things that could have happened to me - miraculous escapes from serious injury or death - that I must say my shadow of luck is marvelous. Or perhaps a better way to express it is that God has been on my side, for which I am most grateful.

Complete set of refraction equipment airlifted to Venezuela (1931).

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Highlights in Petty's History

People often ask me about the accomplishments of Petty over the years. Here are some of them, of which we feel quite proud.

• Invented and developed the first displacement- sensitive seismograph in 1925 which was capable of recording earth movements in their true shape and amplitude, whose sensitivity was unlimited and whose characteristics were all ideal.

• Invented and perfected, in 1925, the first complete seismic system capable of accurately mapping anticlines and deep-seated salt domes with as little as 50 to 100 feet of relief.

• Accurately mapped, in 1926, the Olive Oil Field in Hardin County, which has a total relief of only 150 feet, and made a well location on the high point. See map in appendix.

• Developed and used, in 1926, a short-cut method of locating shallow salt domes without accurately measuring the length of each shot line or recording the times of the explosion.

• Discovered the Pledger Gas Field in Wharton County, Texas, in 1930, which no other crew could detect before the discovery well was drilled.

• In 1931, invented the reverse profile method of reflection shooting which came into practically universal use throughout the world.

• Found the first commercial oil field in England in 1938.

• Invented, in 1952, and patented the CRP method of shooting, now used by practically every company in the world.

• Found, in 1939, the first and largest oil field in India.

• At one time, owned more geophysical patents than any other contractor or oil company in the world, covering inventions too numerous to mention.

• In 1928, Petty accurately mapped a deep-seated salt dome near LaFitte, Louisiana, for a client who farmed it out to Humble Oil & Refining Company (now Exxon) for drilling. Humble reshot it with their own crews but could never find the dome; they drilled it anyway and found an oilfield. They wound up by buying the crew that did the work along with nonexclusive patent rights and reorganized their geophysical department.

• During World War II, Petty had more seismic crews operating than any other company in the world and was working or had worked in Egypt, England, Sumatra, India, Cuba, Venezuela, Ecuador, Trinidad, and Mexico.

• In 1932, Petty contracted their seismic party No. 1 to Sinclair who kept that party under continuous contract for over thirty-five years, said to be a world record.

26

I have never regretted having so hastily resigned my position in Dallas for the half century I have spent in geophysical work has been most rewarding. Not only was it financially remunerative but it put me in contact with so many interesting people, many of whom I still number among my closest personal friends.

O. S. Petty

26

A much appreciated letter from one of our best clients.

SINCLAIR OIL & GAS COMPANY

Sinclair Oil Building
Tulsa, Oklahoma
November 1 1057

OFFICE OF THE PRESIDENT

Mr. O. Scott Petty
Board Chairman
Petty Geophysical Engineering Company
P. O. Drawer 2016

Dear Mr. Petty

It has come to my attention that on November 1, 1957 your seismic party #1 will complete twenty-five years of service under continuous contract to Sinclair. May I extend my congratulations and best wishes on this occasion, and may I assure you the association of our companies has been a pleasant one. I believe you have established a record on this contract.

Your very truly

WILLIAM H. MORRIS

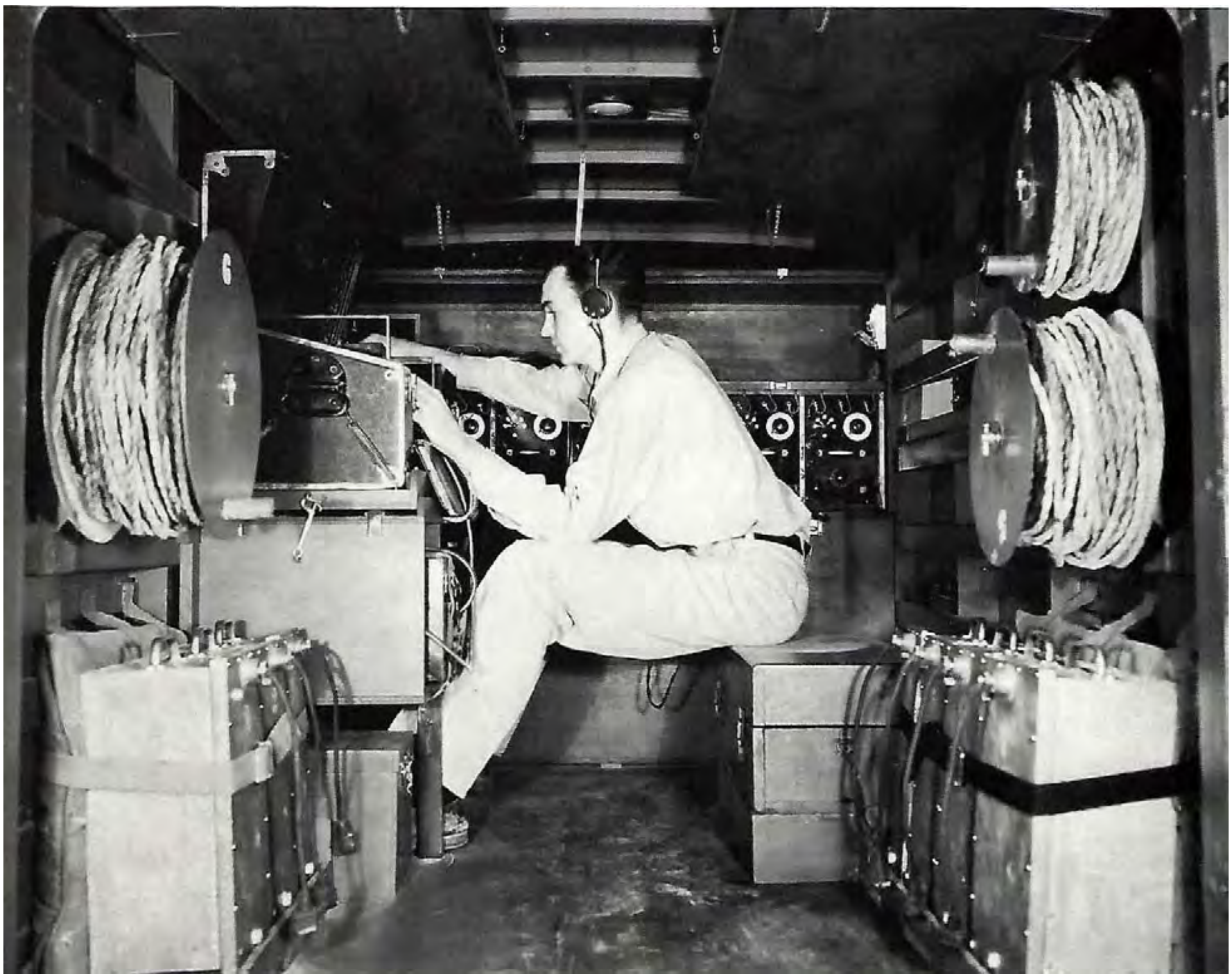
(26)

Petty's first amphibian (1937).

An unusual refraction shot.

The result of 100 pound dynamite shot in a deep hole. The work was being performed in 1932 for Sinclair, which had never employed a seismic crew. They were so pleased, they kept this crew under continuous contract for over 35 years. The structure, located near Laverne, Oklahoma, was mapped and the results conformed to previous geological interpretations.

Petty's third shop and laboratory. Trucks and equipment headed/or Cuba (1936).



W. Lee Moore in observing truck (1931).

A 2,500 pound shot of dynamite in water 50 feet deep.

Moving observing truck in India (/939).

Flying fox killed by crew member with sling shot in India (1939).

The new makes way for the old. A Petty crew working for Burma Oil in India (1939). (Note detector on ground.)

Refraction crew was sold lock, stock, and barrel to Humble, now Exxon (1930).

The Petty Geophysical Museum

The Petty Geophysical Museum is a collection of early geophysical instrumentation, including prototypes, from the period 1925 to 1940. Donated by O. Scott Petty, inventor of the earliest instruments in the collection, these devices are the forerunners of the highly sophisticated instruments of the modern geophysical exploration industry.

Many of these instruments appear in the photos shown in the preceding sections, which, in itself, bears testament to the care and precision with which they were designed and constructed. Most are operational even today.

Along with the instruments in the museum are diagrams, patents, and descriptive cards which help guide the viewer through the exhibit and provide insight into how the devices operate and how they were used. The following section contains all the instruments in the museum and the text is based on the descriptive cards. Additional information has been provided in the text to supplement the cards.

The presentation in the following section cannot impart the same fascination as can a visit, and you are cordially invited to view them in person.

Dedicated on February 10, 1976, the Museum is marked with a plaque in honor of O. Scott Petty, Van A. Petty, Jr., and Dabney E. Petty, founders of the Petty Geophysical Engineering Company.

The Petty Geophysical Museum is located in the Robert H. Ray Building, headquarters for the Petty-Ray Geophysical and Mandrel Products Divisions, at 6909 Southwest Freeway in Houston, Texas.

Part II
Instrumentation

Exhibits

In the beginning (1925), Petty took a systems approach to seismic research aimed at developing hardware and software superior to anything in existence. For over a year, certain major oil companies had combed the coastal plain with crude instruments in their hurly-burly search for shallow domes. The Petty's hoped to keep their efforts secret and, with the aid of independents, to share in the oil found in the deeper structures - the Charenton Field (Louisiana) is an example.

One aspect of Petty's technique was particularly helpful in maintaining secrecy - only a small charge of dynamite in a deep hole was required. Thus, little noise and surface damage resulted. The Chacahoula Dome (Louisiana) was found secretly in 1927 in this way. Another advantage of the Petty technique was that a sophisticated interpretation of faithfully recorded waves could be performed to reveal low relief structures. The Olive Field in Hardin County,
Texas, was such a structure and was mapped in 1926.

The basic element of the system was the seismic detector. Our first model (Exhibit 1) was engineered and constructed as follows:

- Displacement sensitive (condenser plate type)
- Sensitivity adjustable, practically unlimited
- Air damping adjustable to any desired degree
- Natural period of steady mass adjustable
- Friction, practically none
- Capability: Recording vertical component of wave motion in true known amplitude
- Machine work by Charlie Winterborne, Jr.

In my reply to Dabney's letter which sparked the formation of this company I told him that a vacuum tube circuit could be made sensitive enough to measure the deflection of a bar of steel one inch in diameter clamped in a vise that would be caused by the weight of a fly lighting on the end of it. That measurement was made by Professor John J. Dowling at the University of Dublin in Ireland on an instrument he invented which he called an Ultra-micrometer.

I read of Dowling's instrument shortly before receiving Dabney's letter and immediately realized what an ideal seismograph it would make. I promptly bought one from Professor Dowling along with the exclusive patent rights to use it in geophysical work. Obviously it would be equally suitable for gravimetry and that idea was conceived before I even resigned my position in Dallas.
However, seismic work took priority and the gravimeter was not developed until 1929.

(37)

Brief Inaccurate Description of Early seismic Exploration - For Laymen Only

A Shot of **Dynamite** shakes the ground.

A **Detector** senses vibrations and transforms them into a vibrating electric current.

An **Amplifier** amplifies these electrical vibrations.

A **Recorder** makes a visual picture of the vibrations along with time marks and time of explosion which enables a human computer to figure travel times, wave lengths, amplitudes, etc. and **cogitate**.

For the layman, O. Scott Petty has provided this definition, which appears on a card within the exhibit

36

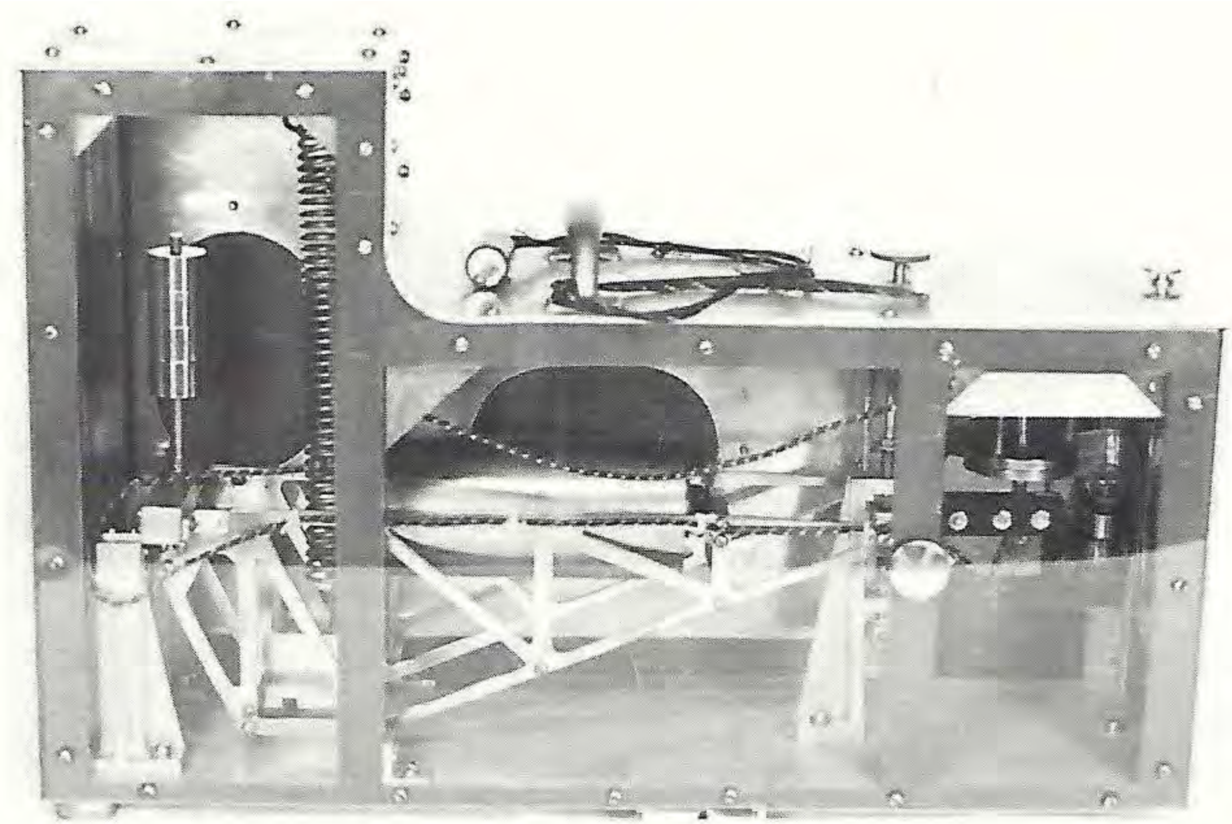


Exhibit 1. Prototype vertical component seismograph detector made by O.S. and Dabney E. Petty, assisted by Edwina H. Petty. (1925)

36

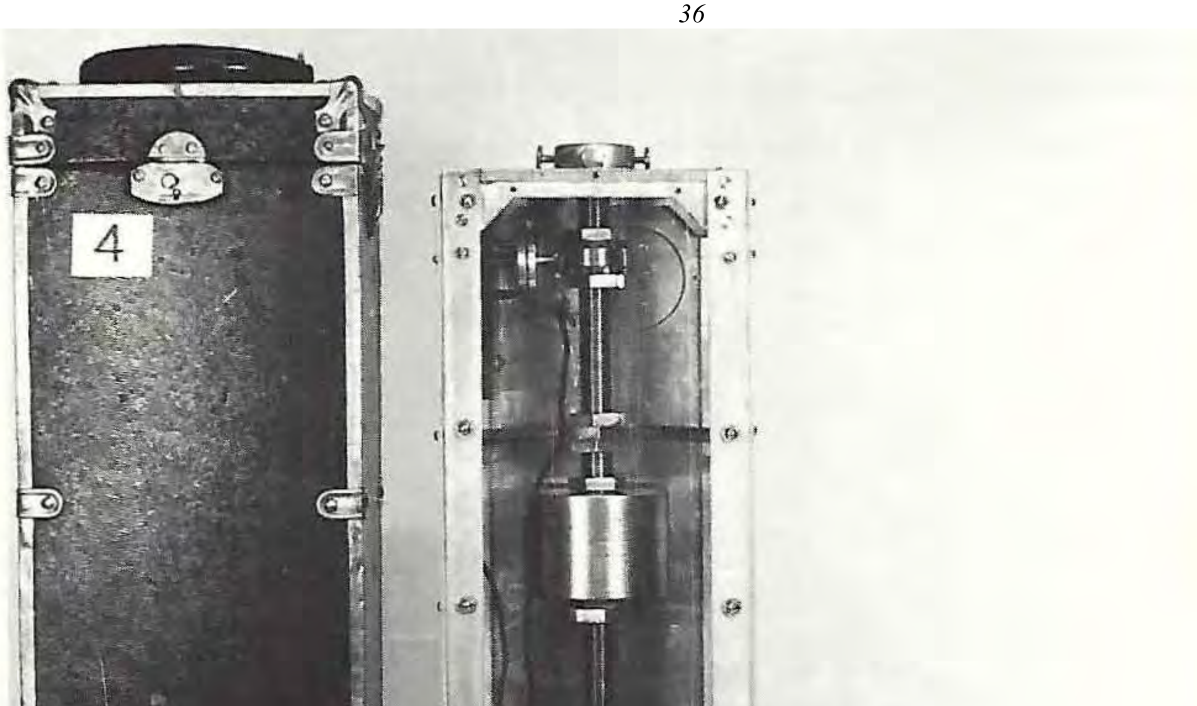


*Exhibit 2. Prototype horizontal component seismograph detector, made by O.S. and Dabney E. Petty, assisted by Edwina
H. Petty. (1925)*

Exhibit 3. The base for the horizontal component seismic detector was driven firmly into the ground and roughly levelled. The detector was set on the base and accurately levelled in line with the shot by means of the levelling screw underneath, then clamped by the clamping screw in front. (1925)

Exhibit 4. Carrying case for horizontal component seismic detector. Before putting detector into case its pendulum was clamped by turning one clamping screw on top so that the condenser plates were separated. Side screws did not touch pendulum shaft but limited its travel during rough transportation. (1925)

The prototype galvanometer recorder (not exhibited) and the instruments shown as exhibits 1, 2, and 5 were used to locate the low relief Olive Field in Hardin Co., Texas, in 1926. This is said to be the first such structure to be discovered by the refraction seismic method in the
U.S.

A shallow well drilled about 1927 by Olive Petroleum Company (the discoverers) was dry. Later Pan American drilled deeper in the same place and got production. The story of this discovery is told in Domes By The Dozen.

MR. O. S. PETTY'S FIRST REFRACTION AMPLIFIER

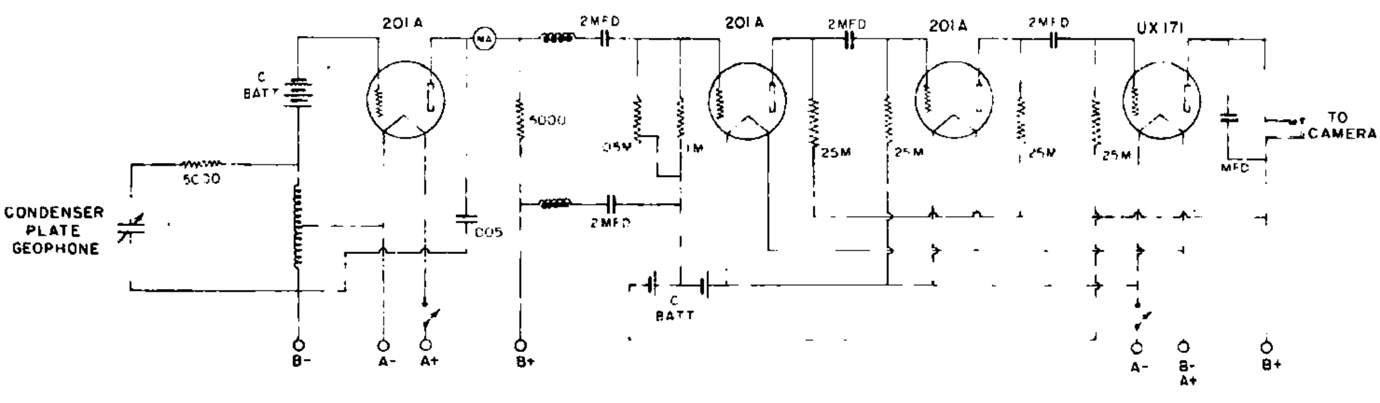


Exhibit 5. Prototype seismic amplifier. This is the only one of these amplifiers ever built. Two wires from the condenser plates in the detector were connected to an oscillating electronic circuit whose output current varied in practically a straight line relationship with the distance between the condenser plates. Amplification was relatively constant between 2 and 70 cycles per second. (1925)

Exhibit 6. Case for transporting and using prototype amplifier. (Exhibit 5). Case copper shielded to reduce pickup of static and 'other unwanted radio waves. (1925)

The prototype recorder, which was stolen, was very similar to the one shown below except that it was carried in two cases instead of one: the camera having its own carrying case and the galvanometer and controls having their own case. In use, the two pieces were set on a common base. It did not have a light tunnel nor was the camera light proof. In simplified terms, the fluctuating current (generated by the detector and then amplified) was passed through a small wire suspended in a magnetic field. As the wire vibrated, a light cast a shadow of wire onto a moving strip of photographic paper. A time marker cast a shadow across the paper each 1/50th of a second.

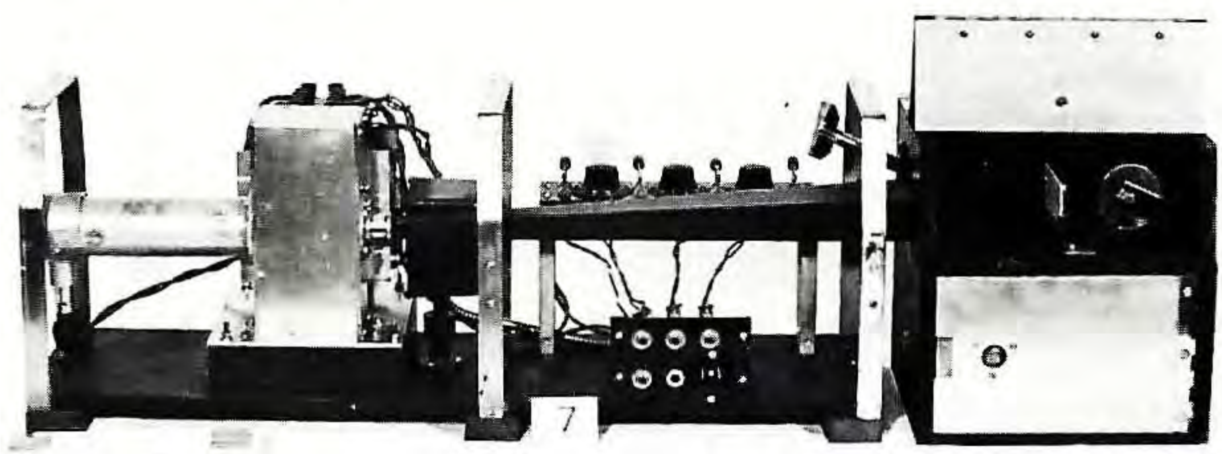


Exhibit 7. Two string galvanometer recorder. (1927). The prototype, invented 1925, was stolen.

Aside from being smaller, lighter, and more ruggedly built this detector (Exhibit 8) had one out standing improvement over its prototype (Exhibit 1) in that the long wires from detector plates to amplifier were drastically shortened. The long wires were in the most sensitive part of the oscillating circuit and the electrical capacity between them changed as the wind moved them. On the record this change looked like ground unrest. Moisture also changed their capacity and caused the plate current to drift. Putting the oscillating circuit inside of the detector eliminated this problem.

This detector was the best, most reliable, and simplest refraction detector that Petty ever made. It was easy to repair and maintain. Many were sent on crews to South America in the late twenties. About the only maintenance they ever needed was replacement of batteries and tubes in the oscillating circuit.

Every vacuum tube used in the oscillating circuit has its own characteristic response curve (plate current versus distance between condenser plates) and not all would operate properly. Carefully selected replacement tubes, along with their response curves, accompanied each detector to the field. This feature made it possible to determine the ratio between the amplitude of the wave on the record and the actual amplitude of the wave in the earth, provided the amplification factor of the amplifier was determined, which it frequently was. On occasion, we checked this ratio by putting a galvanometer directly in the plate circuit, omitting the amplifier. To the best of my knowledge this was the only seismic system that afforded this possibility in those early days.

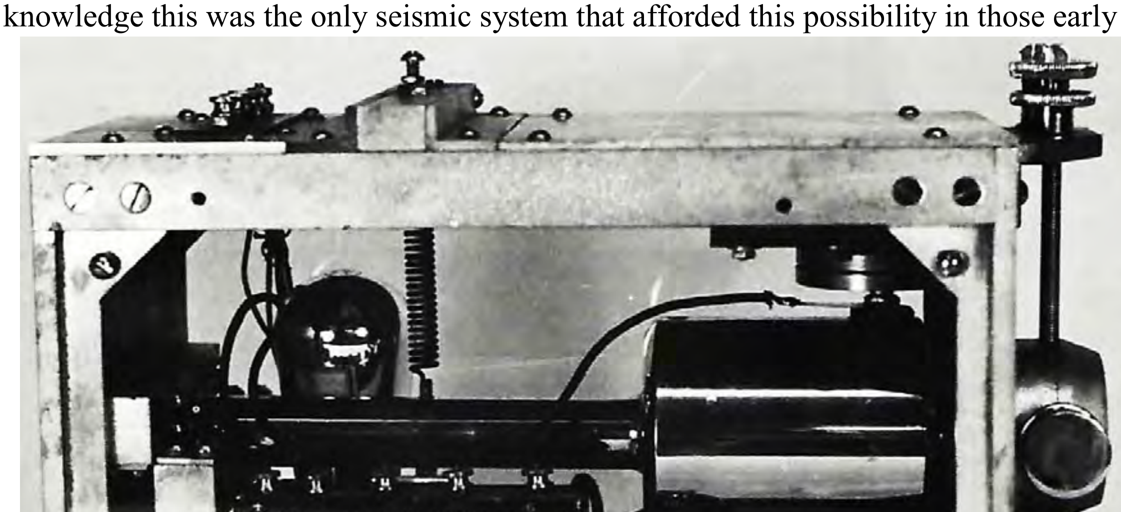


Exhibit 8. After determining optimal characteristics, by field use of the prototype, a smaller and more rugged detector was made. This is the second generation of these new detectors with oscillating circuit inside instead of in the amplifier. (Natural frequency steady mass about 2 cycles.) A solenoid underneath steady mass gave remote control of condenser plate spacing for drift compensation.

40

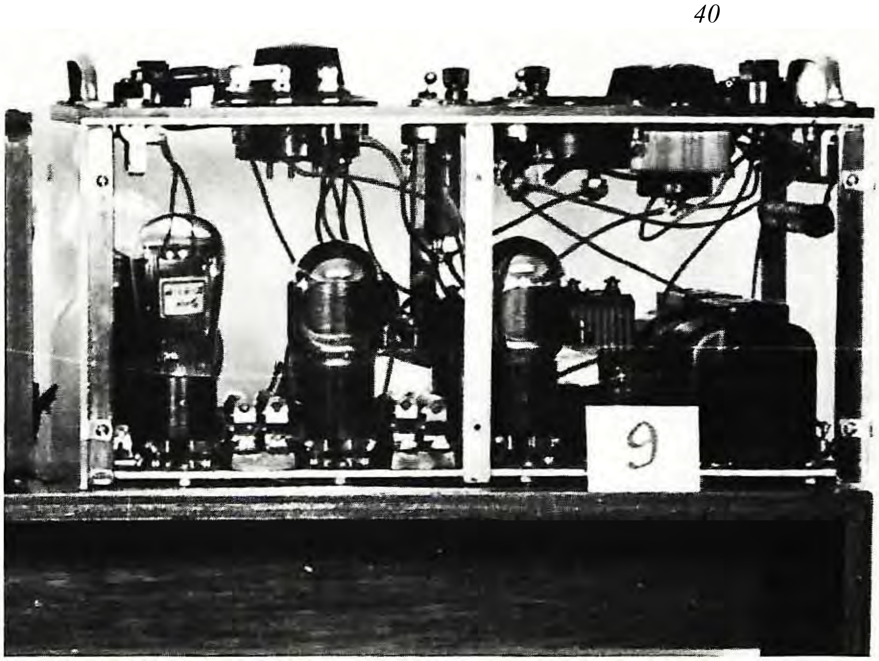


Exhibit 9. Refraction amplifier. This amplifier was used with the detector shown as exhibit 8, which has the oscillating circuit in the detector thereby giving more stability. A milliammeter on the panel and a rheostat in the solenoid circuit enabled the operator to adjust condenser plate spacing as desired. (1928)

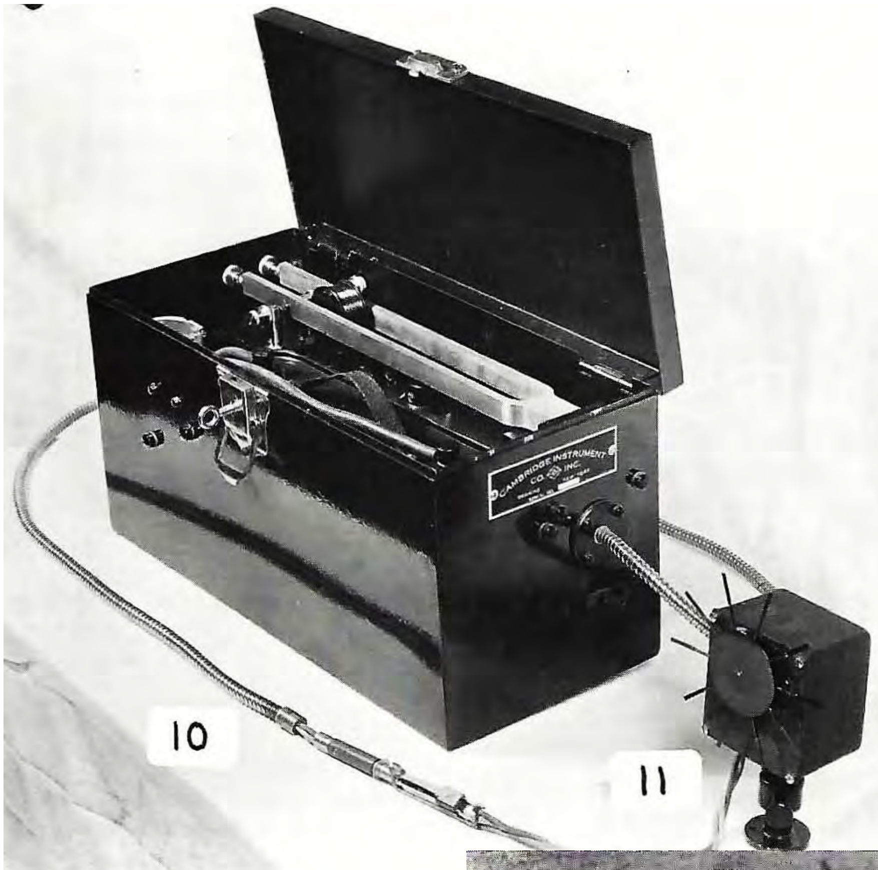


Exhibit 10. Tuning fork. Vibrates 50 cycles per second. Vibrations electrically maintained. Extra contact sends current to synchronous time-marking drive motor in the recorder (Exhibit 7) which puts timing lines on seismic record. (1925)

Exhibit 11. Time marker. Synchronous motor driven by 50 cycle per second tuning fork turns spoked wheel 5 revolutions per second. One of the 10 spokes on wheel cuts off light each 1/50th second.
The wider spokes mark 1/10th and 1/5th seconds. The time marker shown with the timing fork plugged into it is essentially the same as the one in the group picture except for its case. (1925)

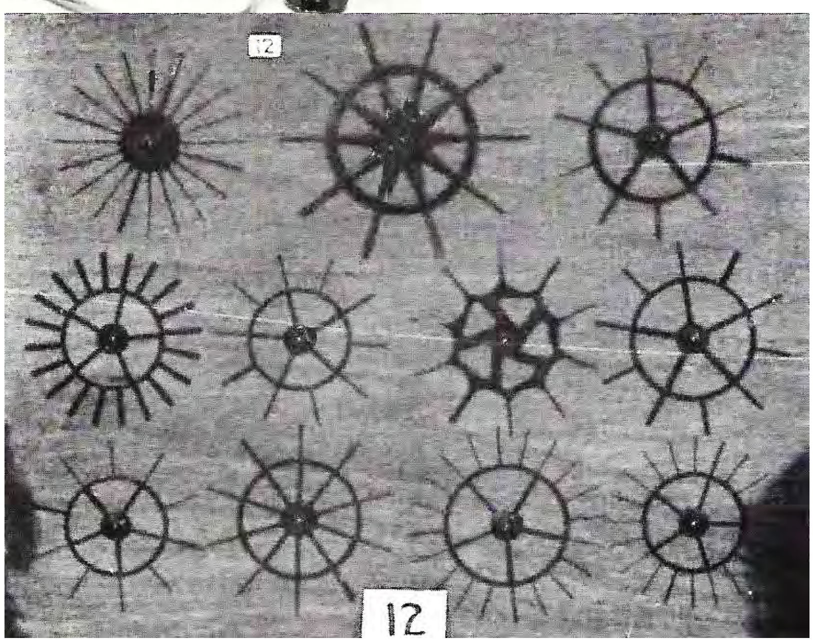


Exhibit 12. Time marker paddle wheel display. These are some of the spoked wheels that were custom made to suit the whims of different seismologists. The spokes made different looking lines across the records and a supervisor could usually recognize records made by different seismologists who took their wheels with them when they changed parties. (Anything to keep them happy!)

The principal on which this detector was constructed was exactly like the detector shown as exhibit 8, the only difference being in the shape of the case and internal parts. It was waterproof, which gave it an advantage over No.8 if it needed to be submerged. Flat bottoms instead of points were furnished for dry land shooting. Its case was brass.

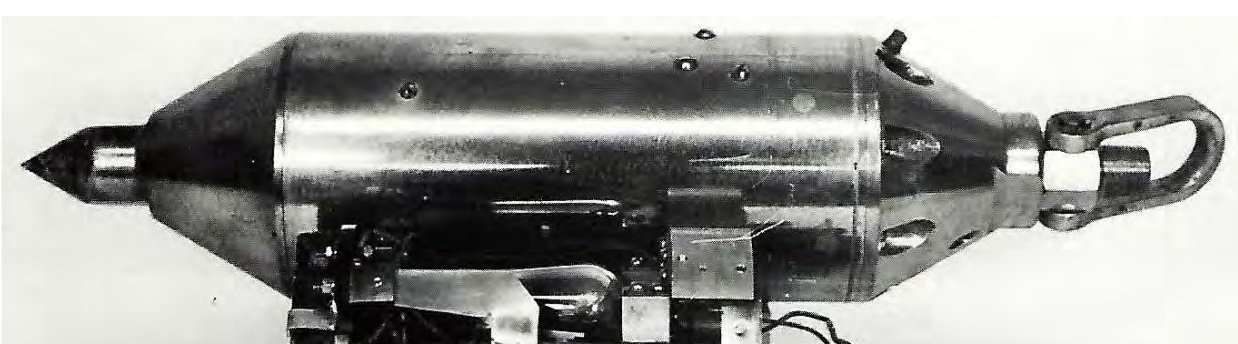
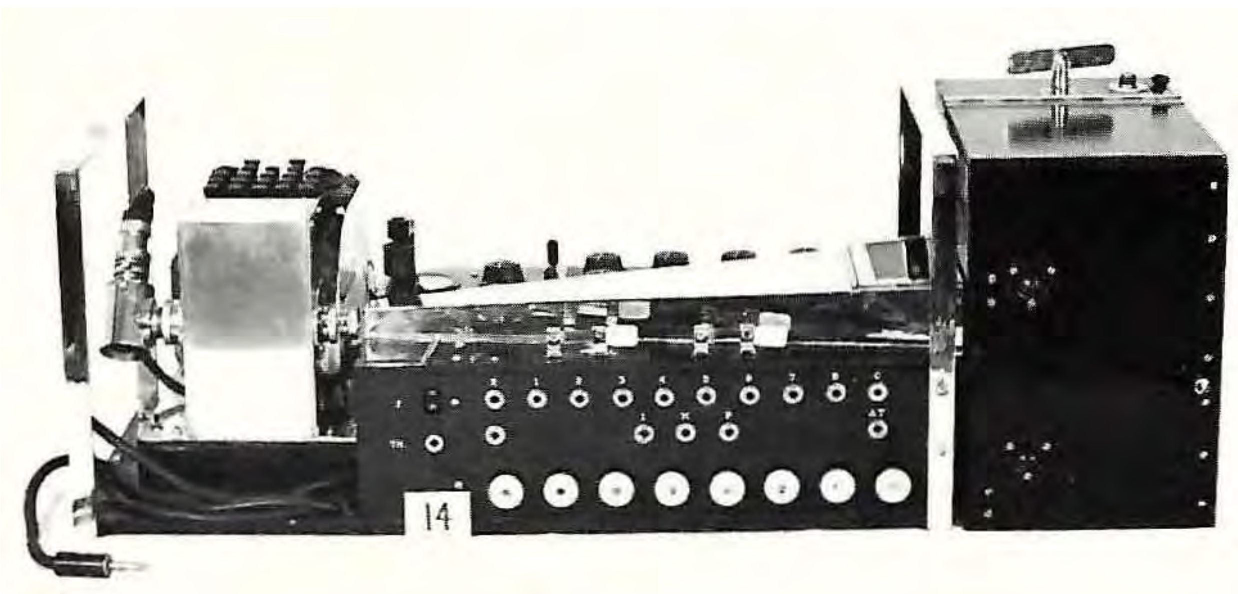


Exhibit 13. Submersible refraction detector. These detectors were made for a special purpose - to be pushed deep into river silt in the beds of big rivers in Venezuela. Heavy chains were attached and detectors were winched out. None were lost (one was stolen). They proved useful in shooting other areas, among them Gulf Coast and Delaware Basin in West Texas for Humble in 1930. (1929)

42

This particular ten-string galvanometer was the subject of a patent interference action between Petty and another contractor and was ordered held in bond by the patent office for use at the interference trial, which was eventually won by Petty. The label shown in the picture below was pasted on the recorder by the patent office



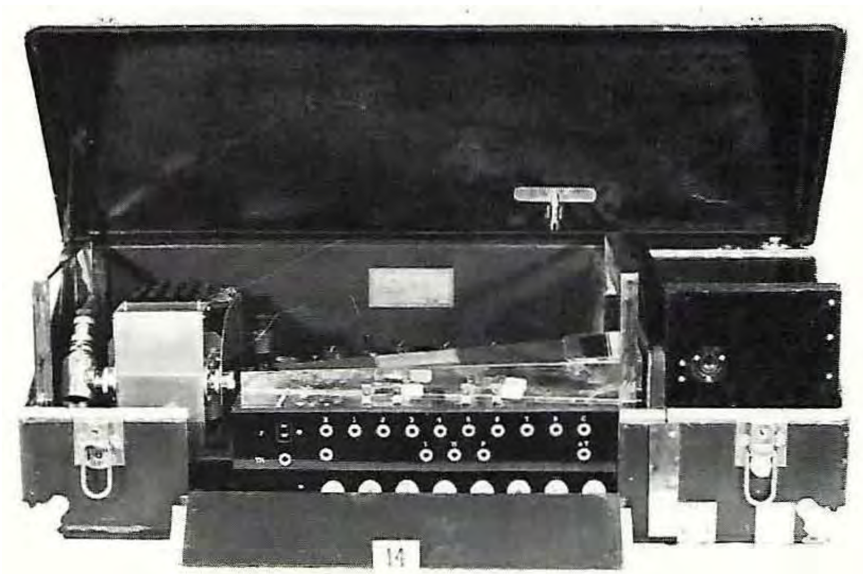


Exhibit 14. Ten string galvanometer recorder. This recorder was held by the U.S. Patent Office (U.S. Pat. 2395427) as the first method to change the frequency response of a seismic system as a function of time - a method which is still in extensive use today. It was also held by the patent office (U. S. Pat. 2365289) as a method to increase the gain of seismic signals as a function of record time. (1931)

Exhibit 15. Ten-string galvanometer and harp display. Similar to one used in Exhibit 14. (1931) The design is as follows:

-ten strings tensioned by coil springs
-tension was field variable
- damped by induction -field variable
-magnetic field produced by electromagnet
-powered by 6 volt storage battery

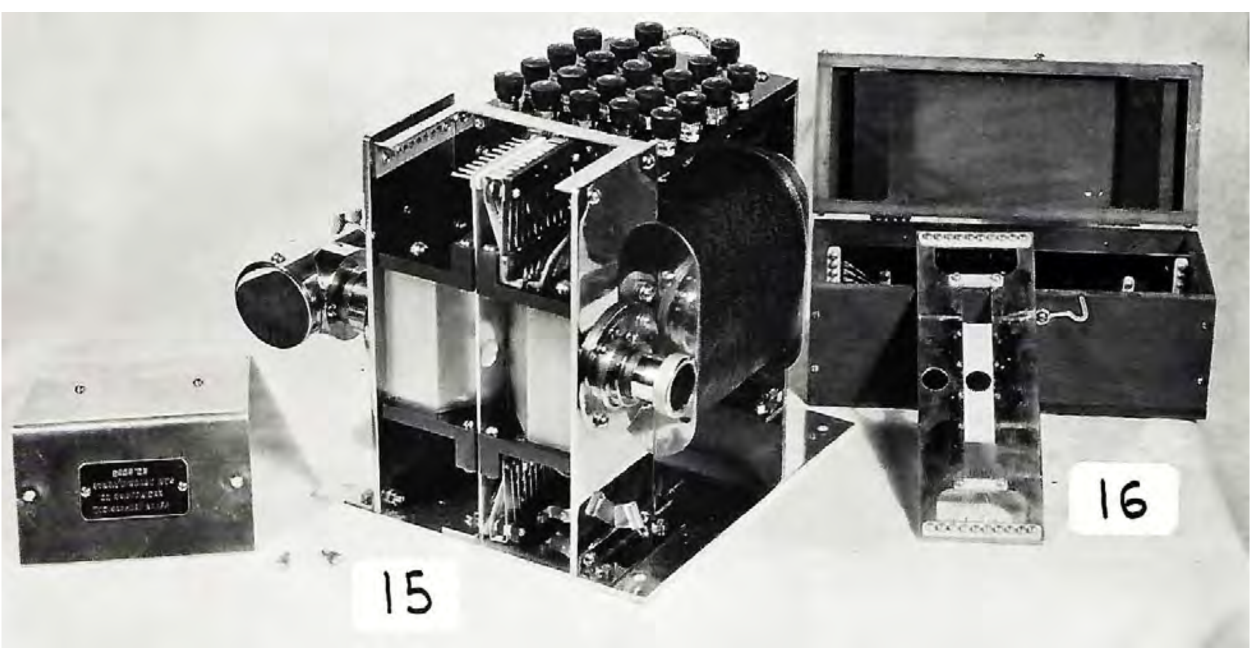


Exhibit 16. Galvanometer harp is made of nickel-plated brass, insulation strips are ivory. Comb is ivory with 10 slots separated by very thin walls. The purpose of the slots is to keep strings from tangling. Strings are phosphor bronze wire 0.001 inch diameter; coil springs are of phosphor bronze, outside diameter of springs 0.01 inch. Strings can be tuned like a violin.

Referring to Exhibit 15, in later designs the magnetic pole faces were cut on a bevel with the optical system, and the strings were staggered so that all were in focus at rest but would not clash during deflection. This prevented flat-topping the waves and a patent was issued to Petty covering this feature. Of course string galvanometers were obsoleted by magnetic recording.

Exhibit 17 was the most novel and complicated detector that Petty ever built. Its outside diameter was only 3 3/4 inches and the length of the brass tube, without spike base and top, was only 8 1\4 inches. It was not very popular with the field crews because it had to be returned to the laboratory for servicing. Only one set was ever made

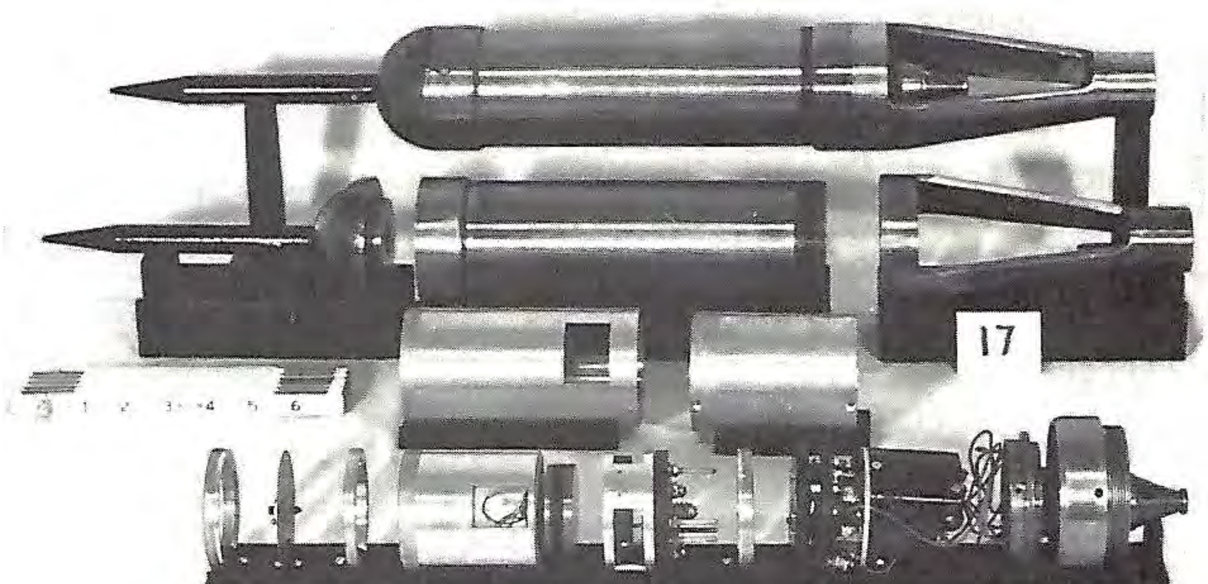


Exhibit 17. Condenser plate refraction detector. The steady mass, centered by use of diaphragms, is magnetically suspended and has a period approaching infinity. Sensitivity of the unit is more than was needed, and the horizontal component is practica1ly screened out. Damping is field adjustable in practically any amount, (1930)

Exhibit 18, Combination reflection-refraction detector. It is the most sensitive seismic detector ever made. This device was used in the discovery of Pledger gas field after it was missed by practically every oil company, and no other seismic crew was able to check it before the well came in. The electronic circuit, including pre-amplifier and batteries, was used as the steady mass. The period was field adjustable from one second up for either reflection or refraction shooting. (1931)

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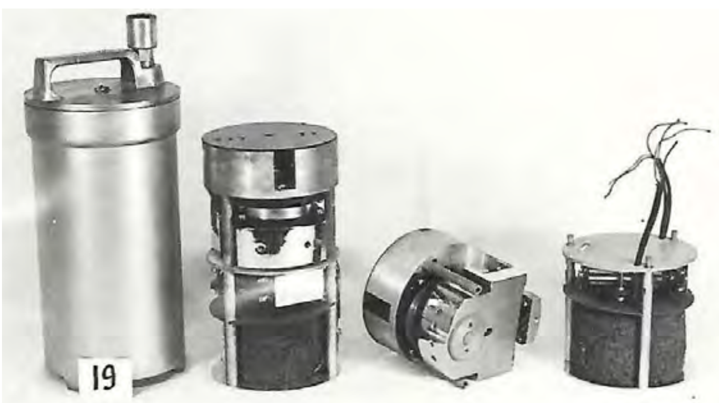

Exhibit 19. Reflection-refraction seismic detector. This was Petty's work horse for many years and discovered, at least for Petty, more hard-to-find oil fields than any other instrument (e.g., the Charenton Field, Louisiana). Its characteristics approach the ideal. (1933)

Exhibit 20. Moving-coil-type refraction detector. This was a special purpose detector. (1942)

Exhibit 21. Reluctance - type seismic detector. Petty preferred condenser-plate detectors for both reflection and refraction use but they were too large and expensive for use in multiple groups. This detector was Petty's standard for multiple use for many years. It was simple, very sensitive, and very rugged. (1933)

Exhibit 22. As more and more multiple detectors were used it was necessary to go to moving coil type detectors. This is Petty's second moving-coil-type detector. It was lighter and could be made more cheaply than the reluctance type (Exhibit 21) but was not as sensitive.

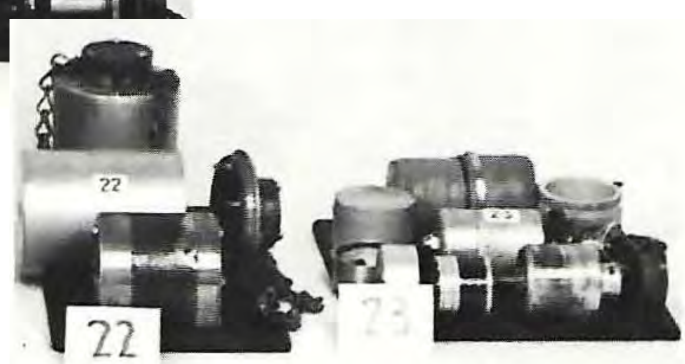

Exhibit 23. Moving coil type detector. As the evolution of seismic detectors proceeded they grew smaller and smaller, and were used in ever-growing numbers. This is the last of Petty made detectors. By this time, they

could be bought more cheaply from those who mass produced them for sale to the industry.

This was, in my Opinion, the finest seismic detector ever made. This type was used for many years by Petty crews all over the world. The crews that discovered the first commercial oil production in England and India, for example, used these detectors. The natural period of the steady mass was adjustable through a wide range as was the damping and the sensitivity. The vacuum tube, used in the oscillating circuit, was wrapped in lead and suspended in the rubber sponge to shield it from ground shock when sitting close to the shot point in reflection shooting. This unit was made obsolete when the use of multiple detectors came into vogue. The patent for this detector is presented in Appendix B for the benefit of those wishing a better understanding of its operation.

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This is the amplifier that was used for many years all over the world with the detector shown as Exhibit 19. This amplifier was the most trouble-free of any Petty ever made. It was made obsolete when the automatic volume control came into general use.

Exhibit 24. Reflection-refraction seismic amplifier. This was Petty's standard until automatic volume control came into use. The unit was designed primarily for reflections but its characteristics were very flexible and it was equally suitable for refractions. (1933)

Exhibit 25. Amplifiers went through an evolutionary process as did other hardware and software. Petty was one of the first to use automatic volume control. This was the third series of amplifiers using AVC.

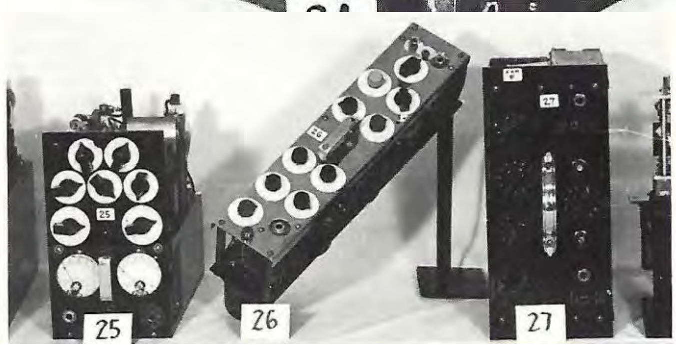

Exhibit 26. Amplifier for tropical use. Climate in the tropics did strange things to electronic equipment, especially amplifiers. Petty sealed the components in this amplifier, - a process not then in general use.

Exhibit 27. This is probably the most sophisticated vacuum-type amplifier ever made for seismic use. It was invented by W. Harry Mayne about 1940 and was known far and wide as "Harry's Model F. "It had push-pull output, double-acting AVC, and "did everything". Petty made tons of them. Then came horizontal stacking (CRP) by Mayne and the need for more and smaller amplifiers.

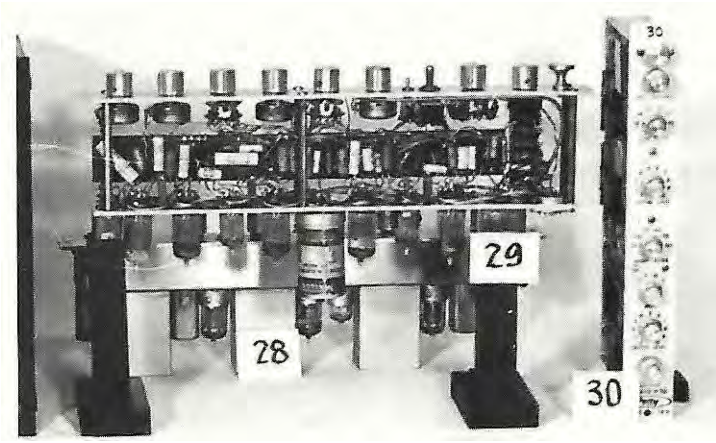

Exhibit 28. Harry's first answer to a smaller, yet sophisticated, amplifier.

Exhibit 29. This model is similar to 28 but the circuit is more easily accessible for servicing in the field. Then came transistors!

Exhibit 30. This amplifier was known as "Harry's TA" and was widely used. It was the first transistor amplifier model by Petty and also the last, as good amplifiers could then be purchased from manufacturers who mass produced them for the industry.

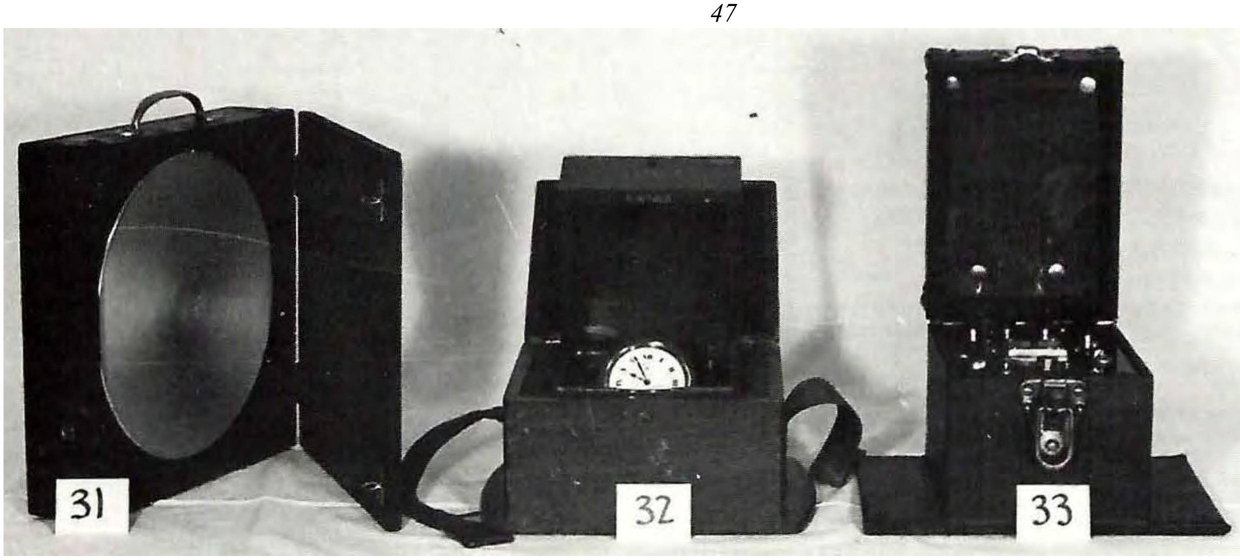

Exhibit 31. This was air wave (sound) detector used in refraction shooting in Venezuela about 1928. In reconnaissance shooting. it saved surface surveying as the distance was computed from the travel time of sound in air.

Exhibit 32. The ticks from this ship's chronometer were picked up by a microphone button and broadcast by the shooter's radio. The observer's radio picked up the sound and put it as blips on the seismic record. Time markers did vary and this enabled the seismologist to reduce all travel times to the same base. Dry holes are known to have been saved by this.

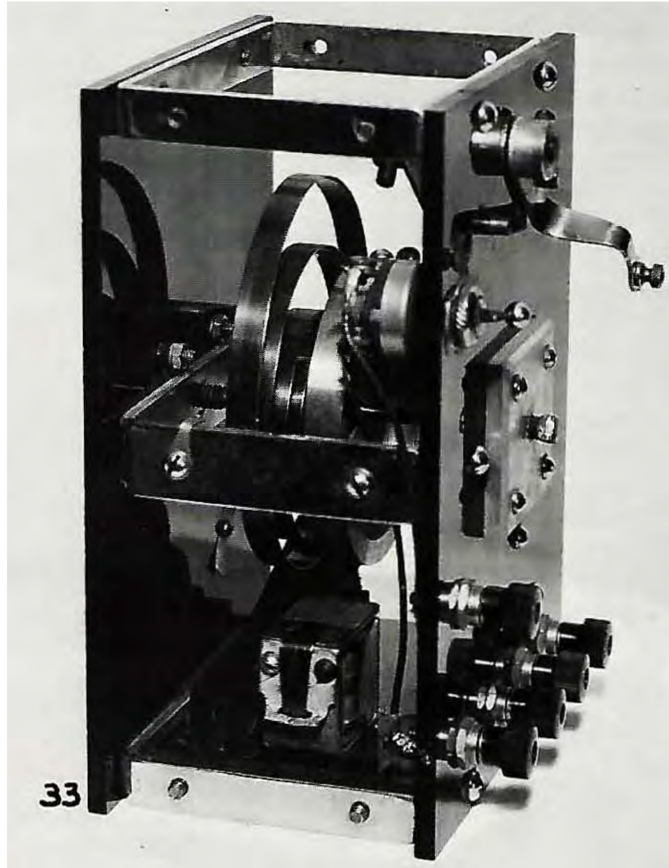

Exhibit 33. Static avoider. The device was cocked before the shot and set off by contact in bottom of blasting machine. It was then re-cocked and sprung once or twice more in long refraction shots. The time between each successive contact is different but constant for each time used. It saved many shots from being lost by static. (1928)

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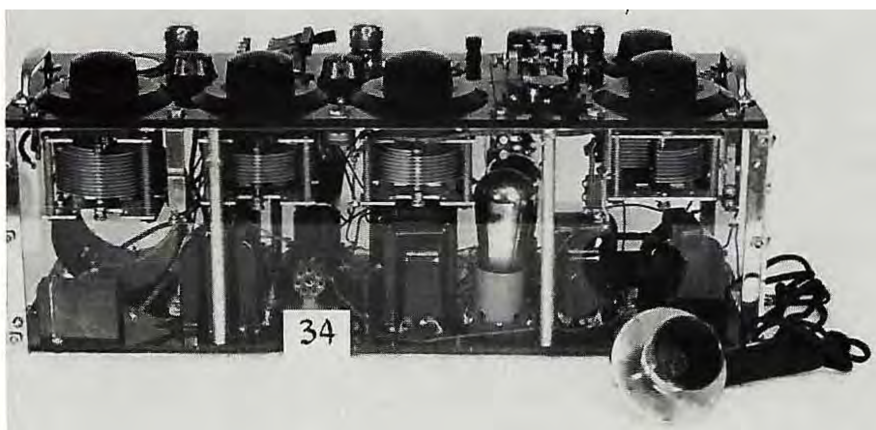


Exhibit 34. Observer's transceiver. Used for voice communication between shooter and observer and to record time of shot by radio.

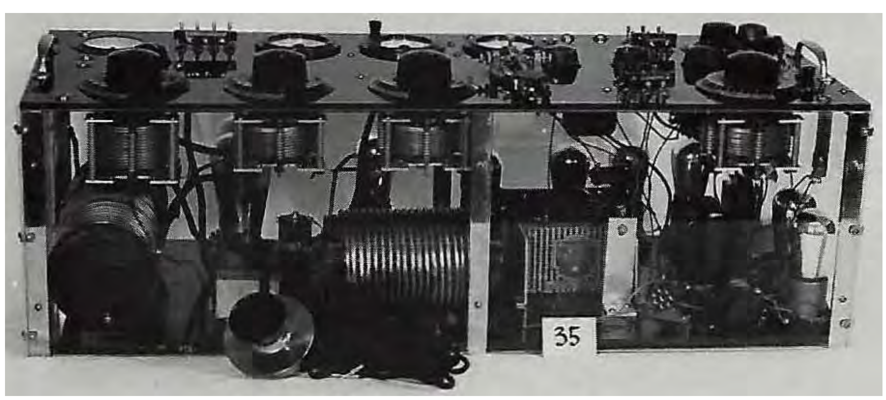
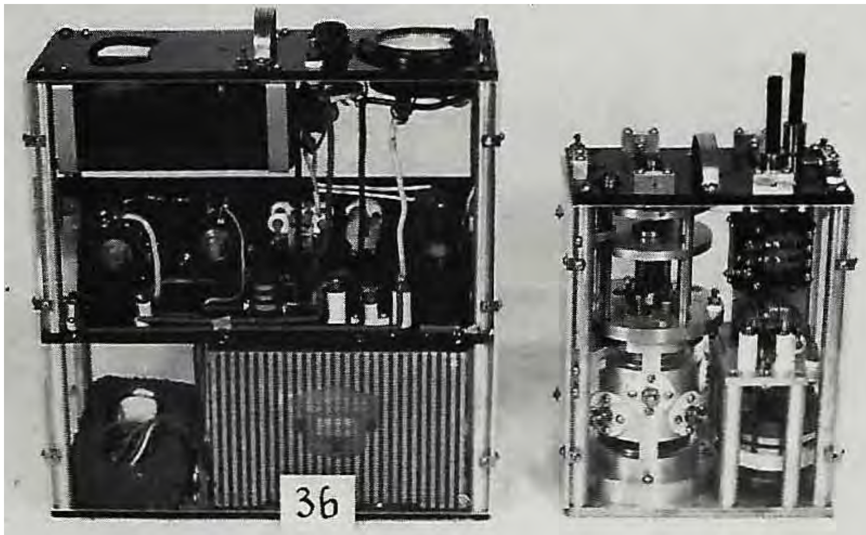


Exhibit 35. Shooter's transceiver. Used to flash time of shot to observers and for communication, voice, or code.

Exhibit 36. Condenser-plate-meter. First field use around



type gravity 1939. (1929)

This invention (Exhibit 36) was conceived in 1925 at the same time the idea for use of Dowling's Ultramicrometer circuit in constructing a seismograph was conceived, but was not reduced to practice until 1929. A copy of Petty's patent is in the case with the instrument available on loan to any interested party.

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As can be seen in the picture, the detector, amplifier and batteries were all in one case. The Shell Company (Frank Goldstone) pronounced it to be the finest refraction seismograph ever built" and insisted it be used on one very difficult job in Cuba although our crew there was supplied with the more modern type cylindrical detectors (Exhibit 13). Mr. Goldstone claimed that Shell usually got better refraction records with less dynamite with this instrument than with any other they had ever used. He attributed this to the size of its base - said it seemed to make more efficient contact with the ground. One fact lent credence to this theory: When a crew needed a refraction record very badly and all else failed, they could sometimes get a good one by setting this seismograph in a muddy location on top of a mound of quakey mud patted down with the back of a spade. Such a base seemed to filter out the high frequency ground unrest and yet not detract from the seismic refraction wave. The unit's size (22 by 16 by 9\6 inches) and weight (about 100 pounds) obsoleted it.

Exhibit 37. The seismograph shown above is the one that discovered the Chacahoula salt dome and can be seen setting on the cypress stump in the picture in which Dabney is shown washing a record. It was the first one built after the prototype shown as Exhibit 1 and is not on display in the museum because it would not fit into the cabinets.

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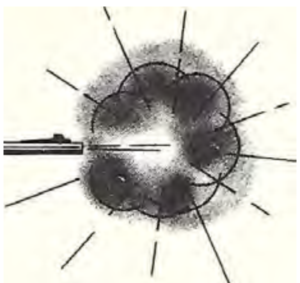
Appendix A
The Secondary Muzzle Flash



THAT SECONDARY MUZZLE FLASH

Ignition of hydrogen-oxygen mix causes it

By NILS KVALE

Most of us who shoot and reload have observed a special kind of muzzle flash, unlike the usually dark red glow that comes an inch or two out of the rifle muzzle when shooting at dawn or dark. That little one isn't really a flash and does not disturb the shooter's eye. It is the last of the burning powder grains and hot gases that push the bullet along.

But the other one puts up quite a show. It's sometimes the size of a football, changing in color from bluish white to a bright, gaudy orange depending on the powder type. It appears just in front of the muzzle, fills the scope sight completely, and even with open sights it can be quite annoying if there's little daylight and your eye pupil is wide open.

What really puzzles many shooters is that this big, brilliant ball of fire doesn't show up with every shot. Well, there are two explanations, one simpler than the other.

First, if you're relatively new in the shooting game you do not always see the muzzle flash. This is because you close both eyes before pulling the trigger. A powder that creates a good-size muzzle flash can be useful to shooting instructors for this very reason. Ask the shooter you are teaching to tell whether there was a muzzle flash and what color it had. If you saw the flash and he claims there was none- you know one mistake he's making. We all did in the beginning.

But there's more to that flash. Even experienced shooters find it missing sometimes. So do the fellows watching, who do not blink, since they have no way of knowing when the shooter will fire. This bright ball of fire is usually known as a secondary muzzle flash, and can be rather simply explained.

Oxygen is needed to make materials burn. Powders have a built-in oxygen carrier, but it turns out that more flammable gases such as hydrogen are produced in the barrel than there is oxygen to burn them. So not all

the hydrogen can hum inside the barrel, but as soon as it gets out the muzzle it forms a highly explosive matter with oxygen from the air.

All that is needed then to produce the bright ball of fire is a spark plug. This can be a still burning grain of powder coming after the bullet, jumping right into the ball of expanding, flammable gases and firing it. Such a burning grain of powder may not always be there, and that is why you do not get a ball of fire with every shot. The gases are there, they do mix with oxygen from the air and become flammable, but when there's nothing to ignite them they flow away and mix with the atmosphere.

One more thing may ignite the gases: their own friction against the surrounding air which they hit at very high speed. *52*
You will recall that your bicycle pump got hot if you were in a hurry inflating a tire. It's the same thing. Air (and gas) molecules rise in temperature from rubbing against each other.

Naval designers have been puzzled by the secondary muzzle flash, too. They always have to consider the effects of flash and the enormous muzzle blasts created by their big guns. Famous battleships have been unable to fire their forward heavy guns as fa r back as the turret could swing since the blast would endanger bridge personnel and less protected crews of the lighter artillery. There's plenty of material for a good sized muzzle flash in a 16" or 18" gun and even with the lighter ones the flash can be quite impressive.

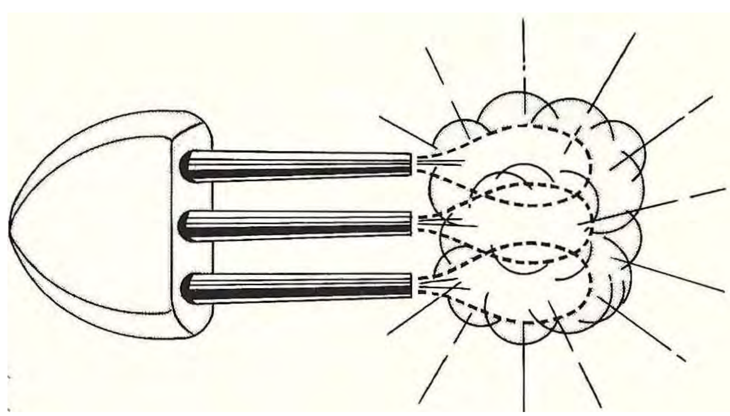
Sometimes there is no secondary muzzle flash when firing one gun, but there is when firing a salvo with two or three guns in the same turret. The reason has been found to be friction. The friction between one ball of gas and the air is not high enough to create ignition temperature, but when the hot balls of gas from two or three barrels hit each other they ignite.

The meaning of "secondary" muzzle flash is undoubtedly easily understandable by now. It is not the initial flash caused by the burning powder, which is hardly visible in daylight, but a flash from ignited gases that did not burn in the barrel.

Experienced shooters claim the secondary muzzle flash increases recoil. There is probably something to this. The exploding ball of gas of course creates equal pressure in all directions and some of this pressure hits the muzzle-the stream of powder gas from the barrel has decreased by then-and pushes the gun backwards. This means a backwards-upwards flip of the muzzle. Besides, the gas exploding in open air is hard on your ears, and in some cases you can actually feel the blast in your face as it tries to push your shooting hat back to full cock.

Remedy? Yes, powder makers put flame dampening mediums in their products, so the secondary muzzle flash isn't the trouble it used to be. If you run across it and find it troublesome, there are so many powders available that you can always find the right one for your caliber-barrel length- bullet weight-velocity combination.

Nils Kvale is in charge of the Export Division Norma Projektilfabrik, Amotfors, Sweden.



When hot balls of unburned hydrogen from two or more naval rifles collide, friction ignites them, causing secondary muzzle flash.

Reprinted from The American Rifleman, May, 1974

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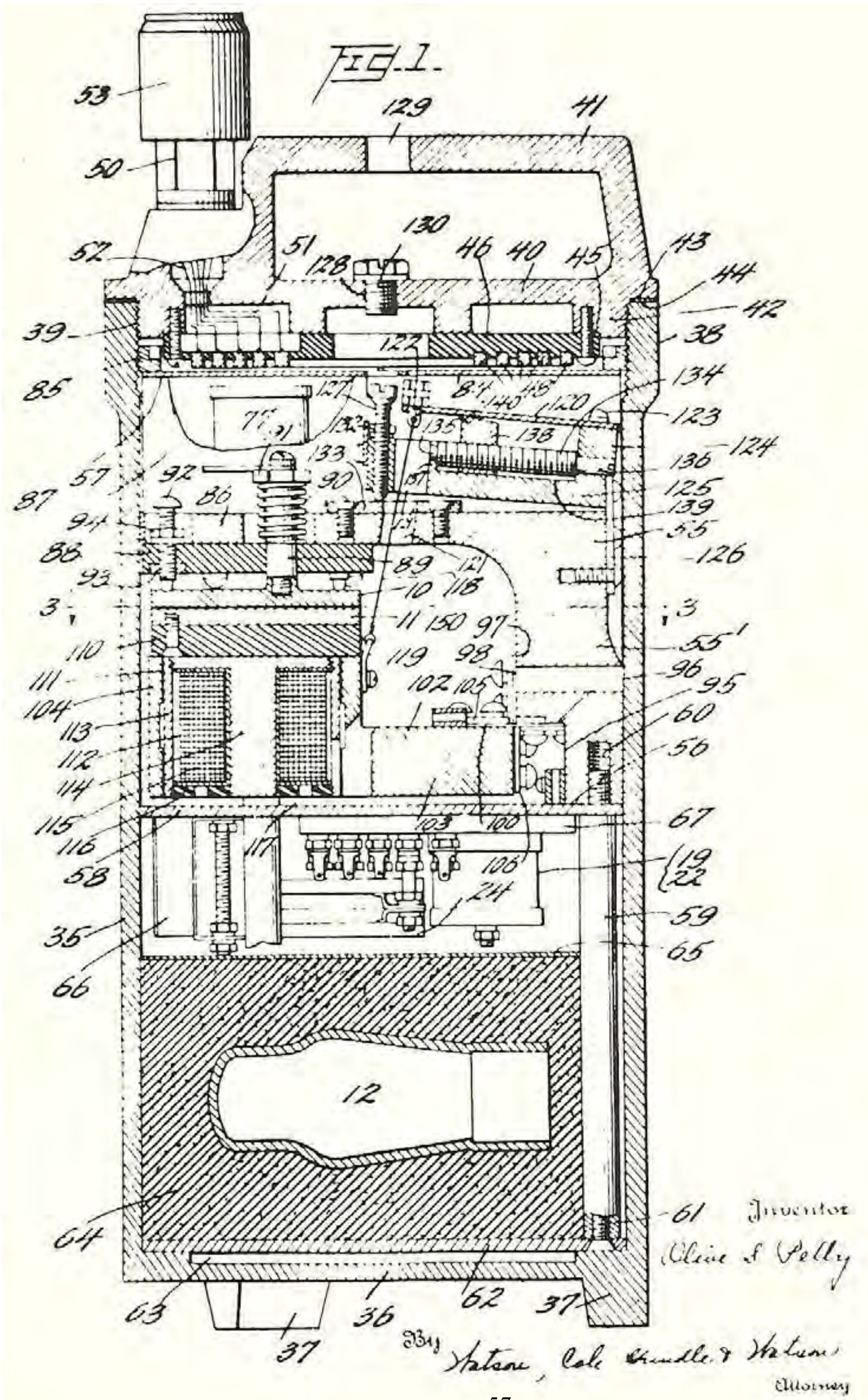
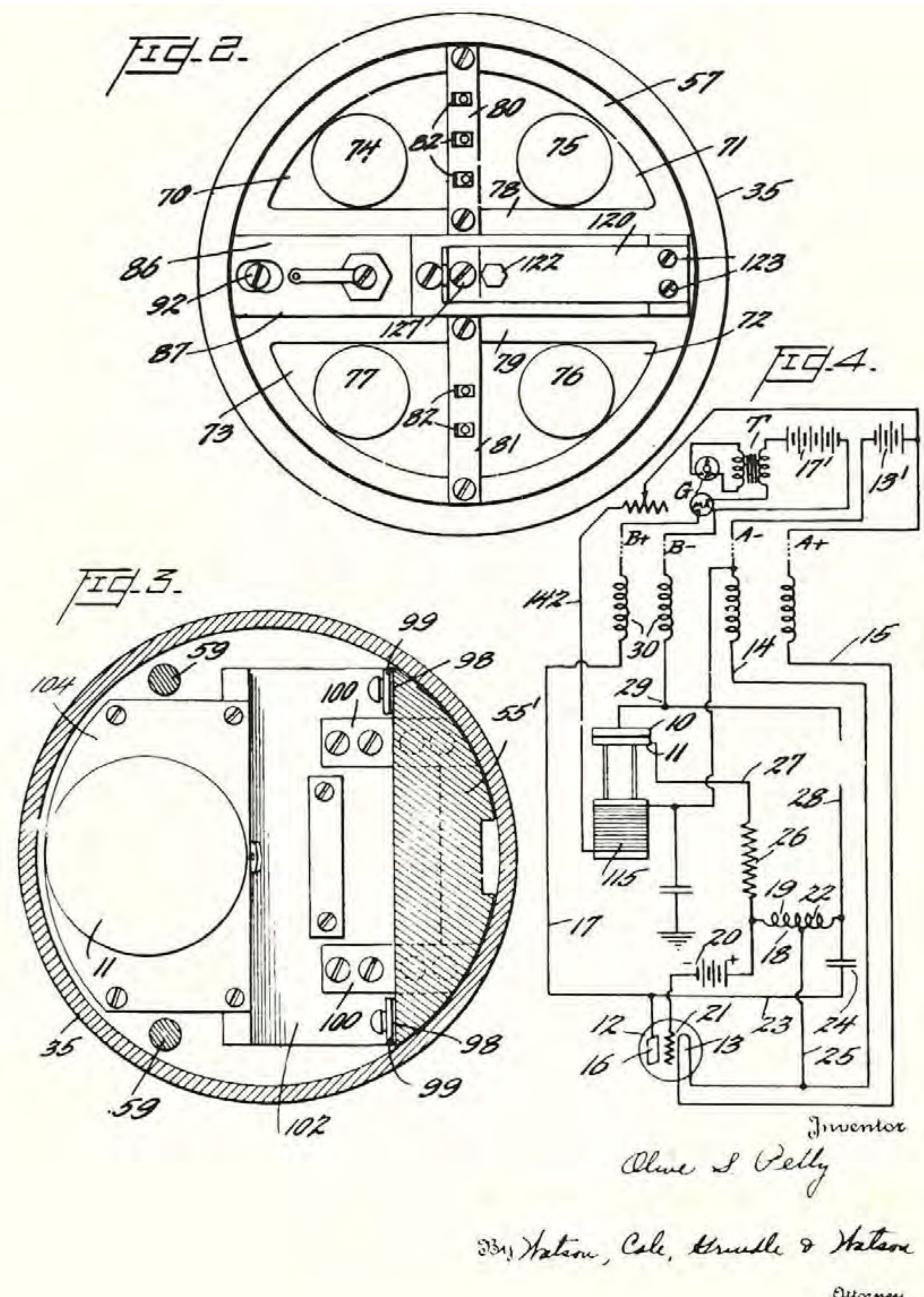
Appendix B
Patent for a Condenser-Type Seismometer

SEISMIC APPARATUS AND METHOD
Original Filed March 14, 1940 3 Sheets-Sheet 1



Oct. I, 1946. **O. S. PETTY** **2,408,478**

SEISMIC APPARATUS AND METHOD
Original Filed March 14, 1940 3 Sheets-Sheet 1



Oct. 1, 1946. **O. S. PETTY** **2,408,478**

SEISMIC APPARATUS AND METHOD

Original Filed March 14, 1940 3 Sheets-Sheet 3

FIG. 5.

Appendix C

Patent For
A Thermionic Vacuum Tube Vibration Detector

Note: Petty held many patents on geophysical instruments, some of which were never reduced to practice because of lack of research and development time. This patent was conceived in 1925 and is shown here because of its uniqueness.

Patented Oct. 1, 1946 **2,408,478**

UNITED STATES PATENT OFFICE

UNITED STATES PATENT OFFICE

2,408,478

SEISMIC APPARATUS AND METHOD

Olive Scott Petty, San Antonio, Tex.

Continuation of Application Serial No. 324,013, March, 1940.
This application November 17 1943, Serial No. 510,685
19 Claims. (CI. 177-352)

1

This invention relates to portable seismometers, intended particularly tor use in conducting geophysical studies of the type wherein an artificial shock is imparted to the earth and the seismic waves emanating therefrom are received, after refraction through certain strata or reflection from various strata interfaces, at one or more seismometer stations which are customarily connected for electrical communication With a recording station equipped with apparatus for producing on a chart one or a plurality of traces, each one representative of changes in the frequency and amplitude of the seismic wave vibrations received by its particular seismometer.

More particularly the invention relates to a portable seismometer of the condenser or capacitive type wherein seismic vibrations cause changes in the relative spacing of a pair of condenser plates so arranged with other impedance elements in an oscillating circuit that the frequency of oscillation is dependent upon and changes with the spacing of these plates. This circuit should have such characteristics that changes in frequency are substantially directly reflected in changes in the plate current of the thermionic tube forming a portion of the oscillating circuit. These changes in plate current are transmitted to the recording station where they serve to actuate appropriate known mechanism for forming the trace.

A number of problems present themselves and each must be solved satisfactorily for the production of a seismometer capable of operation In field service in various parts of the country where temperatures have large ranges and change rapidly: where the characters of the upper and substrata are entirely different; and where various other factors of great variability are encountered.

The apparatus must be sufficiently rugged to withstand rough treatment in handling and transportation; it must be watertight to permit of use in swamps and beneath the surfaces of bodies of water; it must be extremely compact and or comparatively light weight to permit portability. The device must be substantially self-contained; It must be capable at rapid,

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accurate and permanent adjustment of the several elements, and some of these adjustments must be made without opening the casing while others should be capable of change from remote points, such, for instance, as the recording station.

In order to solve the above problems. it is therefore among the objects and features at the present invention to provide a portable seismometer of the condenser type in which:

The whole of the apparatus is enclosed in a watertight housing through which the necessary conductors are passed:

The two condenser plates which are spaced closely to each other are mounted respectively for movement with the housing and with a steady mass hinged thereto;

A novel means of applying and adjusting the balancing or restoring force is provided for setting the plates at a predetermined repose spacing;

Adjustments are provided for the natural period of the seismometer the rate of damping, the spacing of the plates and for other characteristics;

The repose setting can be adjusted electrically from a remote position to permit

adjustment of the sensitivity and frequency responsiveness
of the seismometer:

Novel means is employed for mounting the vacuum tube and other circuit components whereby they are given the greatest possible protection against damage or change in characteristics;

Novel means are used for supporting the framework of the mechanism within the housing and conducting the currents to and from the various electrical portions of the apparatus;

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A novel circuit arrangement is provided which Insures against phase displacement while at the same time producing such changes in the plate current as can be readily transmitted to the recording station without being subject to extraneous fields and the like which might cause variations in the characteristics of the trace.

The apparatus is capable of use in multiple with such spacing between seismometers that the effects of "ground roll"' can be substantially eliminated.

Other and further objects and lesser features of the invention will be more apparent to those skilled in the art upon a consideration of the accompanying drawings and following specification wherein are disclosed several exemplary embodiments of the invention with the understanding that such changes and combinations in and at the features thereof may be made as fall within the scope of the appended claims without departing from the spirit of the invention. This application is a continuation of my co-pending application. Serial No. 324,013. FiledMarch 14. 1940, now abandoned.

In said drawings:

Figure 1 is a central vertical section through a seismometer constructed in accordance with one form of the present invention, the section being taken on a plane at right angles to the axis of movement of the steady mass.

Figure 2 is a plan view of the apparatus with the cover removed;

Figure 3 is a transverse section on line 3-3 of Figure 1 the section plane passing between the two condenser plates;

Figure 4 is a schematic wiring diagram of the Circuits of the apparatus contained within the housing;

Figure 5 is a fragmentary view similar to Figure 3, but showing the thermionic tube mounted on the steady mass;

Figure 6 is a schematic showing of the use of a plurality of condenser seismometers in multiple grouping to reduce or eliminate the major portion of the direct waves; and

Figure 7 is a circuit diagram of the same. In the conduct of geophysical investigations for the determination of subsurface strata disposition, depth, and formation in the search for oil, minerals and the like, it has heretofore been customary to fire a charge of high explosive at some distance below the ground surface and to record from one or more seismometers traces representative of the seismic waves reflected from the strata interfaces and back to the surface, Comparisons of the waves received by the various seismometers at different distances from the source of the earth shock permits a determination, by means forming no part of the present invention, of the desired characteristics of the reflecting surfaces.

The seismometers used have taken a great number of widely differing forms operating on several principles, and that most favored at the present time is of the so-called magnetic type where voltage changes are generated by movement of a
permanent magnet relative to a coil. There are a number of reasons, however, for favoring the capacity type as exemplified by the present invention, particularly in certain locations.

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It is not necessary to go into all of the reasons for the superiority of this type, but one or two important reasons may be painted out. With the construction in accordance with the present invention, the signal to be used at the recording station is transmitted from the seismometer in the form of a high frequency, pulsating direct current, the changes in R, M, S. values of which actuate the recording mechanism. Such a current is less subject to influence by extraneous sources, such as emanations from power lines, static discharges, earth currents, changes in the earth's magnetic field, and the like. The condenser type seismometer of proper characteristics records magnitude of displacements rather than velocities or accelerations and hence produces higher fidelity results with less opportunity for error. Furthermore, it might be said that this type of construction is more readily capable of use and adjustment for sensitiveness, frequency response, damping, rejection of unwanted waves, and for other factors, while capable of being constructed with great ruggedness. The instrument of the present invention is primarily intended to respond to the vertical components of the seismic waves.

Referring now' to the drawings, and first to Figure 4, for an understanding of the operation of tile device of the present invention, there is shown in that figure at 10 and 11 a pair of closely spaced relatively rnovable condenser plates, the mechanical mounting of which will be later described. These plates are incorporated in the oscillating circuit of a three element thermionic tube 12, the filament or cathode 13 of which Is energized by current from A battery 13' through conductors 14 and 15. The plate 16 of the tube is directly supplied with plate current by means of the conductor 11 which is connected to the positive side of B battery 1. The oscillating circuit includes the intermediate tapped inductance coil 18 having the portion 19 which may be referred to as the grid winding and which is connected through the biasing battery 20 to the grid 21 of the tube. The coil also has the section 22 or plate winding connected to the plate by means of conductor 23 in which is interposed the blocking condenser 24 serving to keep the direct plate current out of this oscillating circuit. The intermediate tap of the coil is connected to the cathode by means of the wire 25. The grid coil has its outer end also connected through resistance 26, to plate 11 of the variable condenser by means of the wire 21 while the outer end of the plate coil is connected to the opposite plate 10 of this condenser by means of wire 28 which is also connected a t 29 to the B- lead.

When appropriate potentials are applied to the conductors 14, 15, 17, and 29, the circuit will oscillate at a radio frequency which is dependent upon the characteristics of the various elements of the circuit. The inductances of the two parts of the coil 19, 22 are appropriately selected as well as the value of the resistance 26, condenser 24, and other portions to provide a convenient resonance frequency for any desired fixed spacing of the plates 10 and 11 This spacing can be fixed in repose, as will be later described and adjusted to give the desired frequency of oscillation, so that thereafter, with all of the other elements remaining constant, any changes in the spacing of the plates 10 and 11, will cause corresponding changes In the oscillation frequencies. The usable output from the detector

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travels as a pulsating direct current over the B conductors to the recording station where it Is convenient to position the B batteries as well as the recording apparatus, which for the sake of the present discussion will be considered to include a string type galvanometer G. When the condenser plates are in repose the current feeding the plate is a fixed high-frequency pulsating direct current from the B battery and reservoir condenser 24 to the plate. This pulsating direct current has a frequency outside of the range of vibration of the galvanometer string to which it is preferably coupled by means of a suitable transformer T and hence has no effect in moving this string. However, as later described, substantially all of the radio frequency alternating and pulsating direct currents are confined within the casing of the seismometer.

With the plates at rest, and the circuit oscillating, there is present in the grid coil a high frequency alternating current of fixed amplitude.
The changes in frequency of oscillation brought about by relative movements of the plates 10 and 11 are caused to change the Quantity of current flowing to the plate of the tube as follows. The grid bias Is preferably set for operation in a nonlinear portion of the E_g--I_p curve of the vacuum tube for instance near cut-off by appropriate adjustment of the bias battery 20 so that subsequently applied changes In grid potential of equal value but opposite sign will change the plate current by unequal amounts. Changes In condense plate spacing change the capacity of the condenser and hence the frequency of the oscillating circuit, according to the formula

$$f = \frac{1}{2\pi\sqrt{LC}}. \qquad f = \frac{1}{2\pi\sqrt{LC}}$$

where *f i*s the frequency in cycles per second, L is the inductance in henries, and C is the capacity in farads. Therefore, when the plates move closer together and the capacity of the condenser increases, reduces the frequency of oscillation of the circuit. With this reduction in frequency, the mutual inductance between the two portions of the can 19, 22 will be lessened, therefore decreasing the oscillating voltage applied to the grid by the coil 19. The smaller grid swing will produce a correspondingly smaller amount of rectified plate current. The rectified high frequency portion of the Plate current Is impeded and smoothed by the use of chokes such as the radio frequency chokes 30 shown in conductors 17 and 29 so that the average variation of amplitude, represented by changes in B current at seismic wave frequencies, may be converted to alternating current by the transformer T which couples the seismometer output (through an amplifier, if necessary) to the galvanometer string. It may be considered that the usable output of the seismometer is a current curve averaging the high frequencies. One form of apparatus for assembling in a compact unit the components of Figure 2 and the necessary mechanism for mounting and adjusting the condenser plates 10 and 11 is shown in Figures 1 to 3 inclusive. The outer casing or housing 35 is preferably cylindrical in form and is conveniently a casting of aluminum or similar

metal having a flat bottom 36 and projecting feet 31. The side walls are relatively thin and uniform

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in thickness except at the top where they are thickened as at 38 to provide increased strength to accommodate the threads 39 by means of which the cap or cover is secured in position. This cover may be a casting of the same material including the flat portion 40, the handle 41 and the depending ring 42 threaded to cooperate: with the threads 39 for bringing together the shoulder flange 43 and the upper end 44 of the casing. A suitable water- tight gasket may be interposed here.

The underside of the lid is channeled for stiffness and lightness and is recessed as at 45 to accommodate the annular insulation plate 46 secured in position by screws as shown. This disk has inset in its lower face five coaxial contact rings 48 for cooperation with stationary spring contacts to be later described. An appropriate fitting 50 of watertight construction is provided at one end of the handle in which conventional contact plug receptacles are arranged for connection to the five conductors leading from the rings 48 through the passages 51 and 52. The receptacles are spaced to receive the prongs of a multiple plug 53 to which a five conductor cable is attached for carrying the battery conductors shown in Figure 4 back to the recording station.

All of the apparat.us within the housing is carried by or supported from a backbone 55 in the form of an irregularly shaped and compartmented casing generally circular in outer configuration to closely fit the bore of the casing 35 and having- a substantially flat bottom 56 and flat top 51 . It is preferably formed of some light metal such as aluminum and has kept as light as possible by a cellular construction, as will be' later described. The bottom of the casting 55 is completely closed by a soft Iron cover plate and shield58 which is secured to the backbone by means of one of the three spacing rods 59 which are vertically disposed. This one has a reduced threaded end passing through a hole in the plate 58 and received in a threaded aperture 60 in the casting 55. The others which are attached higher up on the casting 65 are divided at the plate 51 and screwed together to clamp to the plate. The lower ends of these rods are attached by screws 61 to an aluminum base plate 62 adapted to bear against the bottom of the bore of the housing which is counter-bored as shown at 63. The space between the bottom plate and the shield 58 is convenient for the mounting of various at the elements of the electric circuit. For Instance, the thermionic tube 12 Is shown as horizontally positioned and held in place in an aperture in a mass of sponge rubber 64, whereby It Is protected from vibrations and microphonics eliminated.

In this mechanical illustration or the features of the Invention the electric wiring has been omitted for the sake of convenience and clearness. The tube 15 wrapped in lead a s shown in Figure 1 to reduce microphonics and has the usual base prongs cut off and wires directly soldered to the remaining portions thereof. A fiber separator 65 holds the sponge rubber in position and provides space above it and beneath the shield plate 58 for a filter condenser 66 , for the combined grid and plate coils 19, 22 and for the fixed condenser 24 in the oscillating circuit. The C battery 20 and the resistor 26 may also be accommodated in this space, but are not visible in Figure 1.

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These various parts may be conveniently clamped to the iron plate 58 or to an insulating plate 61 beneath the same by means of appropriate fastening elements such as studs or screws.

Figure 2 shows in plan the top of the backbone casting which is provided with four compartments 70, 71, 72, and 73, to receive the radio frequency chokes 74, 75, 76, and 71, which are shown in the A and B battery leads In Figure 4. These chokes serve to keep the high or oscillating frequency alternating currents out of the conductor cables so that there will be no intercoupling between seismometers whose cables lead to the same recording station. These radio frequency chokes are well shielded from each other by the heavy metal of the casting and of the closely fitting cover.

The flat annular top 57 of the casting is notched at diametrically opposite positions as are the parallel vertical walls 78 and 79 separating the radio frequency choke compartments. Each pair of notches accommodates an insulation strip, the one at the upper side of Figure 2 being numbered 80 and the one at the lower side 81. One of these strips mounts three spring contacts 82 and the other mounts two of these contact spaced from the center a distance to engage with the proper one of the con tact rings, 48 so that when the cover is screwed In position the circuits are completed from these spring contacts to their respective rings and the screw cover does not have to be stopped In any special position to insure these connections bring completed.

A thin insulation plate 84 shown in Figure 1, is perforated to pass the sprig contacts 82 and is placed on top of the casing after it and its attached parts has been positioned in the housing and a locking ring: 85 screwed down on top of the same by means of a

spanner wrench.. This serves to clamp the casting and all of its assembled parts lightly in the protecting housing and prevents any relative movement under the severest vibrations.

A portion 86 of the main casting in the form of a transverse septum provides the floor for the compartments housing the radio frequency chokes and for the channel 81 defined by the walls, 78 and 79 and extending at right angles to the contact strips 80 and 81. Closely adjacent the edge of this septum and on its under-face is attached the insulating disk 88 which supports the upper condenser plate 10 which 15 thereby made rigid with the housing and frame of the seismometer. This plate 10, which is preferably made of some noncorrosive material, such as "Monel metal" is eccentrically attached to a post 89 extending from the rear face thereof, as shown, and passing loosely through an aperture in the insulating disk. A helical spring 90 surrounding the portion of this post above the Insulating disk bears With Its lower end on the disk and with its other end on a nut 81 screwed on the post. It serves to bias the plate upwardly and to permit its adjustment for relative height and for paralleling it to the movable plate. These adjustments are effected by three screws having round ends bearing on the back of the plate, one of which is shown at 92, passing loosely through the insulating disk and engaged with the nut 93 below the disk and nut 94

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above the same. By appropriate adjustment of these several screws, and their eventual locking by means of the nuts, the upper plate 10 can be positioned in height and inclination in respect to the portion 86 of the backbone and made parallel to plate 11 in its repose position.

Proper Initial spacing of the condenser plates is best obtained by laying the seismometer on its side with the center line thereof absolutely level and the axis of the hinge of the steady-mass pendulum horizontal. The plates are now adjusted by operation of the adjusting screws 92 so that the distance between them is the correct and desired working distance for use when the seismometer is set on end in its normal position. When the seismometer is placed horizontal the pendulum is permitted to swing free without being pulled by its supporting spring. The proper setting of the plates with the seismometer in this position assures that when the seismometer is set on end the center of gravity of the steady mass will then be in the same horizontal plane as the hinge support. This insures that the seismometer will not pick up horizontal components of earth movements.

For reflection surveys the frequency of the moving system is usually adjusted either to match the reflected wave frequency or to a somewhat higher frequency In order to eliminate as much as possible low frequency "ground rol1." For refraction work it is desirable that the frequency of the moving system be much lower than the frequency of the waves to be recorded so as to get good amplitude of movement at the beginning of the initial impulse.

At the right hand side of Figure 1 and similarly positioned in Figure 3 is shown the relatively thin depending portion 55 of the backbone 55 relieved on its inner left corner as at 95 to provide a substantially horizontal overhanging surface 96. The Inner face of the recess is provided with a vertical surface 97. Both of these surfaces 96 and 97 extend for almost the full diameter of the casing in a direction at right angles to the plane of Figure 1, as clearly seen in Figure 3, for the purpose of widely spacing and supporting the hinge springs tor the steady mass which carries the lower condenser plate 11. There are two sets of these springs, one set 98, the vertical, being more widely spaced apart, and are secured against the vertical face 97, each by a pair of screws as shown clamping overlying metal plates 99 tightly thereon. The other set of hinge springs 100 are between but spread almost as widely as the vertical set. They are horizontal as shown and are secured beneath and against the flat face 96 by fastening elements entering the backbone.

The steady mass 102 is a heavy casting preferably oft brass or other non-magnetic material. It includes the horizontal arm portion 103 adjacent the two sets of hinge springs just described and having a vertical dimension considerably less than the vertical dimension of the weight portion 104. Its top surface is fiat so that the horizontal springs 100 can be secured thereto by suitable fastenings passing through them and tile cover plates 105 while the right hand edge has a vertical surface for attachment of the vertical springs 98

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by similar fastening means and overlying cover plates 106. This type of spring hinge arrangement is entirely free from any looseness whatsoever in any direction, and within the small range of movement can be made to be substantially frictionless and have a minimum of resisting and restoring torque. The two pairs of springs spaced widely apart at opposite sides of the rigid arm insure against any movement of the steady mass in a lateral direction and confine all movement to that about an axis passing through the intersection of the planes of the two sets of springs. The hinge axis is arranged in horizontal alignment with the center of

mass of the steady mass, final adjustment being made by the method discussed above.

The major or weight portion of the steady mass more remote from the hinges is, as previously stated, much greater in vertical height than the arm. In fact it substantially fills the space between the upper condenser plate 10 and the iron, plate 58, leaving only room for the very limited vertical movement of the housing in respect to the steady mass. It is the intention to concentrate as much weight as possible within the limited space and as remotely as possible from the hinge, which contributes to the inertia of the steady mass. Care is exercised to maintain the natural period of the steady mass, as sprung, well outside of the range of seismic waves. If the fundamental frequency of the steady mass, as sprung, is so low that it approaches zero the device very nearly records pure displacement.

The top surface of the steady mass has secured thereto a plate 110 of insulation, which has rigidly attached to its upper surface the lower condenser plate It. Beneath the insulation plate 11, the casting of the steady mass is bored out as at 111 for its full vertical height to accommodate an electromagnet assembly 112, including the soft iron sleeve 113 closely fitting the bore, and having threaded into it the headed core 114, as shown. Between the core and sleeve is the magnet wire winding 115, the lower end of which is closed over by an insulating washer 116. The core and tube define a shell type electromagnet whose central and annular poles are spaced from the iron plate 58 by the small air gap 117, as clearly seen in Figure 1. This air gap may be initially adjusted by a vertical movement of the whole magnet assembly within the steady mass in any desired manner. It is finally locked in position to give the desired air gap for a purpose to be later described.

The weight of the whole steady mass is supported by a cable or wire 118, attached by means of a clip 119 as nearly as possible to the center of percussion of the steady mass. By means of this wire 118 the weight of the steady mass is applied to the outer end of a cantilever spring 120 arranged in the transverse groove 81 in the top of the casting, as previously described. The wire passes through a suitable aperture 121 in the wall 86 of the casting. This cantilever spring is so mounted as to be subject to a plurality of adjustments for fixing the repose position, rate of oscillation, size of condenser air gap, damping, and the like of the steady mass.

The construction of the s print; mounting is clearly shown in, Figures 1 and 2. The spring is a straight flat metal

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plate whose free end supports the adjustable screw terminal 122 to which the wire 118 is attached. The opposite end of the spring is secured by pair of screws 123 to the upstanding lug 124 on a cradle 125 which is hinged just below the attachment of the spring to the backbone 55 of the whole assembly by means of a stiff spring secured to both the backbone and the rear end of the cradle by means of suitable screws;. This cradle carries at its outermost end and beyond the free end of the spring an elevating screw 127 whose head is exactly at the center of the housing so that it is beneath an opening 128 in the cover plate 40 and a corresponding hole 129 in the handle. This permits the use of a screw driver for adjusting the position of the cradle, which in turn changes the position of the steady mass and hence the reposition of the condenser plates. The opening 128, is closed by a suitable plug and gasket, 130 to maintain t the housing watertight. The elevating screw 127 is engaged in a threaded opening in the outer end of the cradle and by means of suitable friction mechanism 132 is prevented from changing its adjustment. Its lower rounded end bears upon a hardened plate 133 secured to the upper face of the partition plate 86 of the casting. A 124 in the cradle floor permits passage of the wire 118.

The cradle carries a second adjusting screw 134 substantially at right angles to the elevating screw and parallel to the spring 120. This screw has its end reduced as at 135 and 136 to provide trunnions in the same bearing holes in lug 137 near the free end of the cradle, and in lug 124, at the hinge and the hinge end. Threadedly mounted on the screw for movement along the same as the screw is rotated is the adjustable fulcrum block 138. The lower face of this block bears closely against the flat surf ace 139 of the cradle which is parallel to the axis of the adjusting screw and sufficient friction is available here to insure against looseness. The upper end of the block is inclined to provide the sharp fulcrum edge 140 upon which the spring 120 bears. Adjustment of the block 138 by the rotation of the screw 134 determines the active length of the cantilever spring and hence the period of the steady mass and its rate of movement in respect to the housing and thus fixes the range of the response of the seismograph in accordance with the known rate of vibration of the seismic waves with which It is to operate. In most regions, it is found that these waves have a frequency of from 20 to 70 cycles per second.

The size of the gap between the condenser plates 10 and 11, when in repose, which may be adjusted by the elevating screw 127, determines at least partially, the damping of the steady mass, because of viscosity of air between plates

18 and 11 which damping, however, is a condition controlled by several other factors and more particularly by the electromagnet previously described. The damping which it affords is, however, not the primary purpose of the magnet.

The winding of this magnet, as shown in Figure 4 is connected between the A - battery source 14 and a conductor 142 which returns to the recording station, passes through a suitable rheostat, and is connected to the A+ terminal, inserted in the circuit may be an appropriately graduated ammeter to roughly adjust the strength of the magnet, although this Is not required since the primary purpose of the magnet is to fix the

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spacing of the condenser plates10, and 11 just prior to the time of taking a reading. The rheostat permits a remote adjustment here, since the magnet in attracting the iron plate beneath it acts in opposition to the cantilever spring and provides a means for not only increasing the pull on the spring, but for remotely adjusting the gap between the condenser plates. The size of this gap can be very accurately read at the control stat ion by the use of a milliammeter MA In the plate circuit of the tube. It will be recalled that this plate current bears a definite and known relation to the frequency of oscillation of the tube and, once having calibrated the system, the gap between the condenser plates can be accurately determined, for instance, in fractions of a millimeter by a reading of the milliammeter at the recording station, if such factors as A and B voltages are held reasonably compensated for. Remote adjustments of the condenser plate gap is important to permit compensation for temperature changes and other transient variables.

Where it is desired to have the seismometer operate about a certain fundamental frequency of the output current while yet permitting changes in plate spacing to adjust the damping in accordance with external conditions, the frequency can be adjusted by varying the current in the tube filament.

In Figure 5 is shown a further embodiment of the seismometer In which the thermionic tube 12A has been removed from the position shown in Figure 1 in the sponge rubber mass to a mounting on the steady mass in the space designated in Figure 1 by the reference character 150 and lying just above the arm portion of the steady mass. As shown, the tube is secured to the steady mass arm by a pair of metal bands 151 passing around the same and compressing sponge rubber cushion strips between the bands and the surface of the tube.

By placing the tube as just described, several advantages are gained. In the first place, the tube is so mounted that it is not subjected to the seismic shocks since the steady mass is intended to remain stationary while the remainder of the seismometer moves about it. In the second place, several inches in vertical height can be cut off of the detector, reducing both the volume and weight of the same. Where these devices are used in difficult terrain, and far from base, they must be transported by trucks, by pack animals or by human carriers, so that any saving in size or weight is extremely valuable. Thirdly, the weight of the steady mass is increased without any attendant total weight Increase In the seismometer.

Condenser type seismometers constructed according to the present invention lend themselves particularly well to ganging or multiple use for the purpose of reducing or entirely eliminating the pick-up of ground waves. As is well-known in seismology, the waves of largest amplitude which reach the seismometers as the result of an explosion are in most cases those travelling in the surface or weathered layer of the earth, or very near the same, and since they do travel so close to the surface they follow nearly the shortest path, and are often the first to reach the various detectors. In any event such waves have amplitudes much greater than those of the wanted reflected waves. If the apparatus is made sensitive enough to

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record the desired waves with a proper dene of amplitude on the chart, then the unwanted waves are recorded with such over-intensity as to be detrimental to the equipment and to extend off of the recorded chart. The time of arrival of the first of these waves may be of importance but the remainder of them are of no consequence and merely serve to confuse the recording.

In accordance with the present invention the above difficulties may be partially or entirely eliminated by ganging a number of condenser seismometers In place of the usual one at each station and spacing them apart in the line of approach of the ground waves at approximately one-half wave length intervals so that their outputs substantially cancel each other. The reflected waves, however, having more nearly a vertical component reach the units of this gang of seismometers almost simultaneously and thereby augment each other, thus increasing the size of the wanted record and decreasing the size of the unwanted record, making them more nearly of the same order. Since the first seismometer in line is affected without corresponding cancellations from the

others when surface waves fist arrive the time at arrival will be nicely shown on the chart.

Reference to Figure 6 will make this arrangement clear tor there is shown at 200 the weathered layer of the ground with the shot point 201 arranged just below this layer for better transmission of the artificially propagated seismic waves and at 202 is shown an assumed reflecting surface whose depth is not in proportion to other spacing's on the chart because of lack of space. The surface at the ground Is shown to be formed into exaggerated waves 20a representing the 80-called "ground roll," "ground wave" or the like, and four condenser type seismometers 204, 204a, 204b, and 204c are shown positioned on the surface of the ground in a line with the shot point and with the spacing 205 between centers of any adjacent pair preferably equivalent to substantially one-half wave length of the "ground wave," The length of this wave, In most any type of weathered layer, Is a matter of record or can be ascertained before-hand very simply, great exactitude In this matter Is not essential. It will be seen from the position of the waves that any two adjacent seismometers arc either in phase opposition or are at a substantially neutral point and at the same amplitude. Two might be sufficient but four are preferred, arranged in circuit as shown in Figure 7.

For the purpose of this arrangement seismometer 204c is identical with that previously described in this application and the circuit is the same as that of Figure 4. The remaining seismometers, however, can be much simpler and may include only the mechanical parts as disclosed in the several previous figured together with the variable condenser plates. Thus in Figure 7 seismometers 204,204a, and 204b are represented merely by condenser plates although at course they include the adequate mechanical mounting tor the same so that the plates will respond exactly as the ones in the seismometer described in detail above. The condensers of each of the four seismometers are set to substantially the same plate spacing and are connected in parallel as shown. Then, by appropriate adjustment of the proper elements the tube circuit

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is made to oscil1ate at the desired frequency but under the control of all four of the sets of condenser plates. It will be seen that it two of these are widely opened and two others are brought closely together the total change in capacity of the set will be practically zero so that the total effect of "ground roll" will hardly be noticeable. When, however, reflected waves are received, the condenser plates of the several seismometers move substantially In unison and thereby exert an augmented control on the frequency of oscillation of the circuit, resulting in greater changes in the output.

For purposes of convenience it might be desirable to have the auxil1ary seismometers 204, 204a' and 204b also equipped with the magnetic coil for determining their repose setting hence their damping as well as control of the oscillating circuit.

With the arrangement just described no additional conductors need be returned to the recording station above the number required when a single seismometer is used. It will be appreciated that a plurality of seismometers arranged in a row and connected to control a single oscillating circuit give an output averaging the "ground waves". It they are placed sufficiently close together, they become the equivalent of a continuous flexible condenser and it is within the import of this invention to include such a continuous condenser which should have a length not much greater than one-half wave length. It might be constructed in the nature of a coaxial cable with suitably resilient spacers or it could take other forms, and in each case be connected to an oscillating circuit of the type described to give an average result. It would of course give a summation for reflected waves.

Whi1e the invention has been illustrated as applied to a seismometer of the capacitive type, certain features of the invention pertaining especially thereto. It will be apparent from the foregoing description that certain other features, for instance the provision for indicating and remotely controlling the spacing of the relatively movable elements of the seismometer, are applicable to various other types of instrument, such as the electromagnetic type, the reluctance type, the piezo-electric type, and various types less commonly employed In which accurate determination of the repose portion of the movable element Is desirable.

Having thus described the invention, what is claimed as new and desired to be secured by Letters Patent Is:

1. In a portable seismometer of the condenser type, in combination. a housing, a condenser plate rigidly supported for movement with the housing, a second condenser plate spaced closely to the first, a steady-mass mounting said second plate and being hinged to the housing for movement relative thereto in a direction at right angles to the planes of said plates, spring means biasing said second plate toward the first one, and adjustable magnetic means acting between the housing and steady-mass for adjusting the plate spacing against said bias.

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2. In a portable seismometer of the condenser type, in combination, a housing, a condenser plate rigidly supported for movement with the housing, a second condenser plate spaced closely to the first, a steady-mass mounting said second plate and being hinged to the housing for movement relative thereto in a direction at right angles to the planes of said plates, spring biasing means supporting the steady-mass and acting to move the same about its hinge in one direction only, and a magnet carried by said steady-mass and arranged to exert a force to always oppose the effect of said means.

3. In a portable seismometer of the condenser type, in combination, a. housing, a condenser plate rigidly supported for movement with the housing a second condenser plate spaced closely to the first a steady-mass mounting said second plate and being hinged to the housing for movement relative thereto in a direction at right angles to the planes of said plate-so means acting to move said steady-mass about its hinge, magnetic means for opposing the effect of said means, and means to adjust the strength of said magnetic means to vary the initial spacing of said plates.

4. In a portable seismometer of the condenser type for use with other elements to form an oscillating circuit and including relatively movable condenser plates the spacing of which determines the frequency of oscillation of said circuit, means mounting said plates for relative position change in response to seismic waves and including biasing means tending to fix the normal plate spacing , and means adjusted remotely from the seismometer and adapted to oppose said biasing means to thereby adjust the initial set ting of the plates and thus the oscillation frequency.

5. In a portable seismometer of the condenser type, in combination, relatively movable condenser plates, means mounting said plates for relative position change in response to seismic waves and including biasing means tending to fix the normal plate spacing, and electromagnetic means having an adjustable pull in opposition to said biasing means whereby adjustment of the repose spacing of the plates may be effected remotely from the seismometer.

6. In a portable condenser type seismometer for operating a remote recorder, in combination, a closed housing adapted for movement in response to seismic waves, steady-mass hinged to said housing, a pair of closely spaced condenser plates secured respectively to the said housing and steady-mass for relative movement, a vacuum tube in said housing impedance elements incorporating said tube and plates in to a circuit oscillating at a frequency dependent on the spacing of said plates, a source plate current for said tube, said circuit being such that changes in said oscillation frequency cause corresponding changes in the plate current, an electromagnet mounted in said steady-mass, an armature fixed to said housing below said magnet, a source of current for said magnet, and means to adjust said current to vary the plate spacing to determine the repose value of said plate current.

7. In a portable seismometer of the condenser type, in combination, a housing, a condenser plate rigidly supported for movement with the housing a second condenser plate spaced closely to the first, a steady-mass mounting said second plate and being hinged to the housing for movement relative thereto

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In a direction at right angles to the planes of said plates, spring means carried by the housing for supporting said steady-mass, said spring means comprising a cantilever spring, means suspending said steady-mass from the free end of said spring, and an adjustable fulcrum for said spring.

8. In a portable seismometer of the condenser type, In combination, a housing, a condenser plate rigidly supported for movement with the housing, a .second condenser plate spaced closely to the first, a steady-mass mounting said second plate and being hinged to the housing for movement relative thereto In a direction at right angles to the planes of said plates, spring means for supporting said steady-mass from the housing, said spring means comprising a cantilever spring, means suspending said steady-mass from the free end or said spring, a cradle tor said spring supported on said housing and having the opposite end of said spring secured thereto, a knife edge fulcrum for said spring slid able in said cradle, and means to adjust said fulcrum longitudinally of the cradle.

9. In a portable seismometer of the condenser type, in combination, a housing, a condenser plate rigidly supported for movement with the housing, a second condenser plate spaced closely to the first, a steady-mass mounting said second plate and being hinged to the housing for movement relative thereto in a direction at right angles to the planes of said plates, spring means for supporting said steady-mass from the housing, said spring means comprising a cantilever spring, means suspending said steady-mass from the free end of said spring, a cradle tor said spring supported on said housing and having the opposite end of said spring secured thereto, a knife edge fulcrum for said spring slidable in said cradle means pivoting the spring-attached end of said cradle to said housing, and means to move said cradle about its pivot to change the repose spacing of said condenser plates.

10. A portable condenser type seismometer including in combination, a closed bottom tubular metal casing, a metal closure cap for the same, a

backbone casting immovably mounted in said casing and having a recess therein, a steady-mass and attached lever in said recess, means hinging said lever to said casting, means suspending and providing a restoring-force for said steady-mass, a pair of closely positioned condenser plates, one supported by said casting and the other by said steady-mass, a thermionic tube and oscillating circuit elements in said casing, and connected to said condenser plates said tubes and elements being so positioned as to be shielded from each other, from the condenser plates and external fields by the casting and steady-mass.

11. A portable condenser type seismometer including, in combination, a tubular metal casting, a closure cap for the same, a metal backbone casting immovably mounted in said casing and having a recess therein, a steady-mass and attached lever in said recess, means hinging said to lever to said casting, means suspending and providing a restoring force for said steady-mass, a pair of closely positioned condenser plates, one supported by said casting and the other by said steady-mass, a thermionic tube and oscillating circuit elements In said casing and connected to said condenser plates, and casting having compartments therein, certain of said circuit elements being positioned In said compartments for electrostatic shielding.

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12. A portable condenser type seismometer including, in combination, a tubular metal casing, a closure cap for the same, a backbone casting Immovably mounted In said casing and having a recess therein, a steady-mass and attached lever in said recess, means hinging said lever to said casting, means suspending and providing a restoring force for said steady-mass, and a pair of closely positioned condenser plates, one supported by said casting and the other by said steady-mass.

13. In a portable seismometer of the condenser type, in combination, a housing, a condenser plate rigidly supported for movement with the housing, a second condenser plate adapted to have a close repose spacing adjacent the first, a steady-mass mounting said second plate and being hinged to the housing at a distance laterally of the plates for small range movement In a direction at right angles to the planes of the plates, the axis of the hinge being In the same horizontal plane as the center of gravity of the steady-mass: movable-plate assembly, whereby the seismometers unresponsive to horizontal components of seismic waves.

14. A portable condenser type seismometer responsive to vertical displacements comprising, in combination, a supporting member adapted to be moved by seisms, a condenser plate carried by said member, a steady-mass, a second condenser plate on said mass, means movably suspending said steady-mass from the supporting member with said condenser plates in close proximity, said suspending means being resilient and providing a restoring force for said steady-mass after displacement, an electric circuit associated with said condenser plates as to be influenced by their spacing, means In said circuit to record the Instantaneous spacing of said plates, means In said circuit Independent of said last named means to Indicate the repose spacing of said plate, and means remote from the seismometer to adjust the repose spacing of said plates.

15. In a portable seismometer of the type employing elements which are readily displaceable on application thereto of seismic wave energy, in combination, a housing, an element rigidly supported in the housing. a second element supported in the housing for movement relative to said first element, and means mounting said second element to permit such relative movement, said means Including a steady-mass carrying said second element, said steady-mass being hinged to the housing on an axis laterally spaced from said elements, the hinged axis being disposed substantially in the horizontal plane containing the center of gravity of the steady-mass, whereby the seismometer is unresponsive to horizontal components ot sel8mlc waves.

16. A portable seismometer responsive to vertical displacements comprising. In combination, a supporting member adapted to be moved by seisms, a first element carried by said member, a steady-mass, a second element on said mass, means movably suspending said steady-mass from the supporting member with said elements in close proximity, an electric circuit so associated with said elements as to be influenced by their spacing, means in said circuit to record the instantaneous spacing or said elements, means in said circuit independent of said last named means to indicate the repose spacing of said elements, and means remote from the seismometer to adjust the repose spacing or said elements.

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17. A portable seismometer responsive to displacements, comprising a casing, a steady-mass supported from said casing, and means for generating a voltage which is a function of the Instantaneous displacement between said casing and said steady-mass, separate means tor recording said voltage, separate means tor indicating at a remote place the average spacing between said casing and said steady-mass, and means to adjust the average spacing between said casing and said steady-mass from a remote place.

18. In a portable seismometer responsive to vertical displacements, in combination, a housing, a

steady-mass hinged to said housing, means for generating a voltage which is a function of the instantaneous displacements between said housing and said steady-mass, the axis of said hinge being in the same horizontal plane as the center of gravity of said steady-mass, whereby the seismometer is unresponsive to horizontal movements.

19. In a portable seismometer responsive to vertical displacements, in combination, a housing, a steady-mass hinged to a said housing, means for generating a voltage which is a function of the displacements between said housing and said steady-mass, the axis of said hinge being in the same horizontal plane as the center of gravity of said steady-mass, whereby the seismometer is unresponsive to horizontal movements.

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INSTRUMENT FOR DETECTING VIBRATIONS

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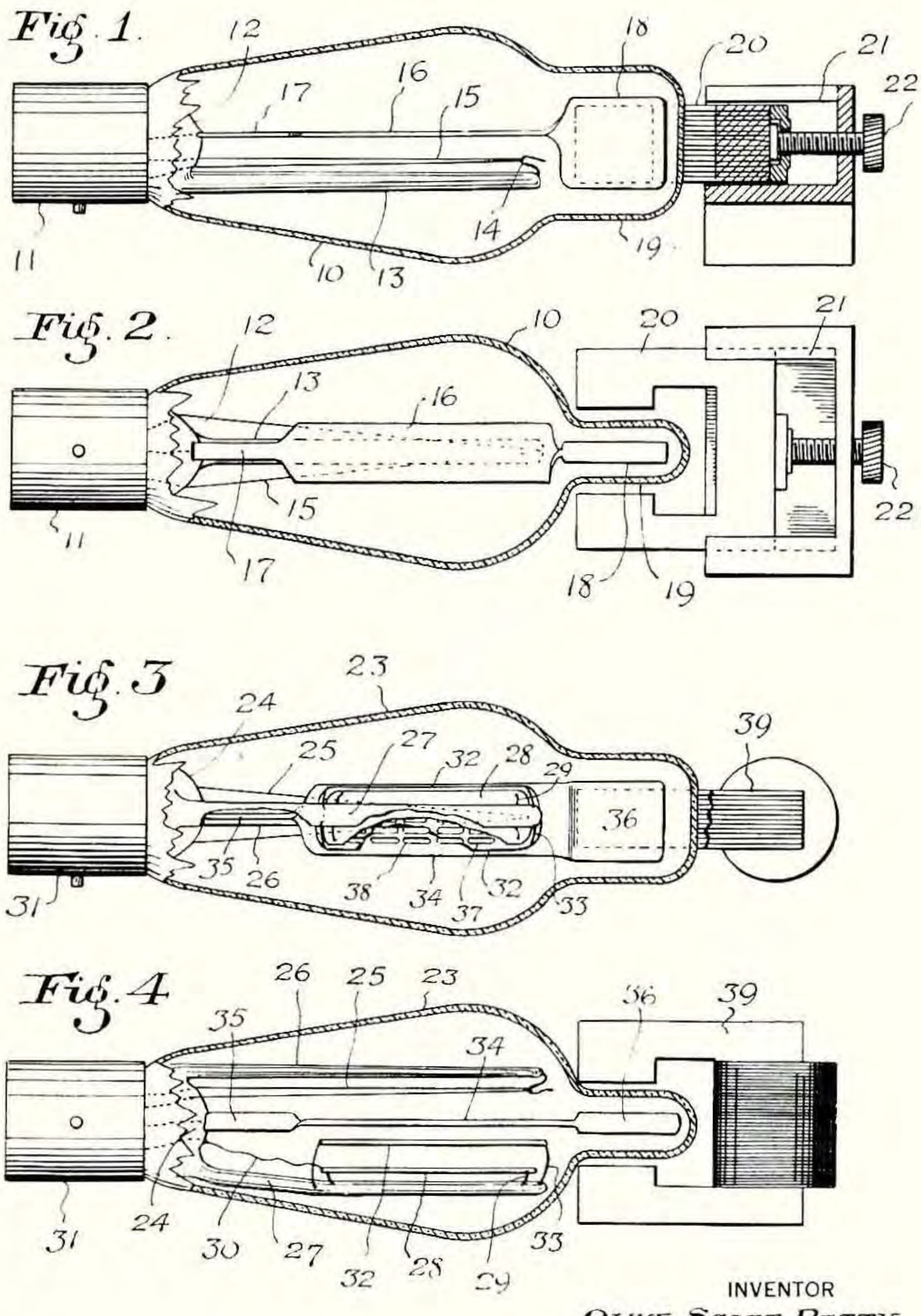

INVENTOR

OLIVE SCOTT PETTY

BY

ATTORNEY

June 21, 1932. O. S. PETTY **1,864,214**

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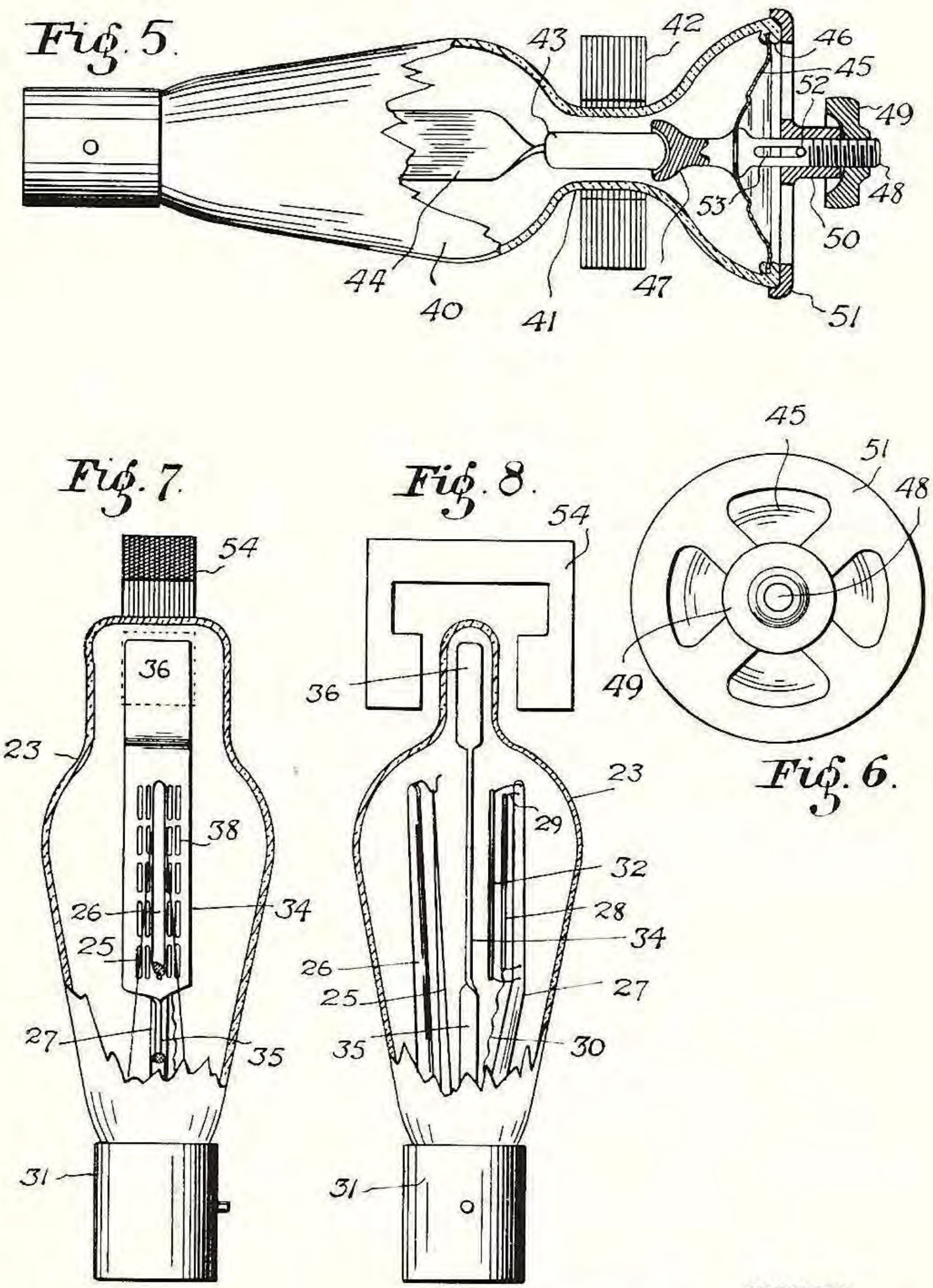

INVENTOR
OLIVE SCOTT PETTY.
BY
W. Wallace [signature]
ATTORNEY

Patented June 21, 1932 1,864,214

UNITED STATES PATENT OFFICE

OLIVE SCOTT PETTY. OF SAN ANTONIO. TEXAS

INSTRUMENT FOR DETECTING VIBRATIONS

Application filed March 27, 1928. Serial No. 265,068.

This invention relates to an instrument for use as a seismograph or for detecting, observing, indicating or recording mechanical or elastic vibrations or motions and although the device may be utilized for recording distant earthquakes or for recording or detecting vibrations in bridges, buildings and other structures or the vibrations in machinery and the like, it is specially adapted for use in applied geophysics more particularly to detect or record sound waves produced in the earth and air by the detonation of charges of explosives for the purpose of obtaining data or records which may be studied with a view to determining underlying geological formations.

One object of my invention is to provide an improved instrument of small compact and conveniently portable form for use in transforming mechanical or elastic vibrations or motions into fluctuating electric currents for the purpose of observing, indicating, detecting, or recording vibrations or motions.

A further object of this invention is to provide an instrument of the character above described in which a pendulum steady mass is enclosed within and is constructed as an element or a part of an element of a two or three element thermionic vacuum tube.

With these and other objects in view the invention consists in the novel construction and arrangement of parts hereinafter described, illustrated in the accompanying drawings, and particularly pointed out in the appended claims, it being understood that various changes may be made without departing from the spirit or sacrificing any of the advantages of the' invention.

In the drawings: Fig. 1 is a side view and Fig. 2 is a plan view both partly in section showing one form of the device for detecting the vertical component of the motion: Figs. 3 and 4 are views corresponding to Figs. 1 and 2 respectively but showing a modified form; Fig. 5 is a view corresponding to Figs. 2 and 4 but showing another modified form; Fig. 6 is an end view of the same; and Figs. 7 and 8 are elevations looking at right angles to each other and both partly in section showing a form of the device suited for the detection of the horizontal component of the motion.

In the device shown at Figs. 1 and 2, for detecting the vertical components of motions a vacuum tube or casing 10 is formed with a plug 11 with the proper contacts (not shown) on the end thereof for engagement with the contacts in a suitable receiving socket. An internal stem part 12 is provided with a rod 13 having a hook 14 for supporting the filament 15 and extending from the stem

12 in spaced relation to the filament 15 is a plate 16 having a resilient portion 17 and

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a weighted portion 18 and adapted to serve as the pendulum or steady mass of the instrument, and as the plate 16 forms part of the steady mass and as the filament 15 moves with the other parts of the device, the distance between the plate and the filament varies and fluctuations are thus produced in an electric current flowing from the filament 15 to the plate 16 and such fluctuations are detected and observed, indicated or recorded in any suitable or well-known manner and if so desired amplification may be readily effected by means of an ordinary vacuum tube amplifier. The weighted portion 18 is made of copper -and is free to move in a flattened extension 19 formed on the end of the casing 10; and in order to properly damp the movements in accordance with the well-known principles of seismograph construction a damping magnet 20 is mounted so as to embrace the portion 18. This magnet 20 is mounted in a guide 21 and has an adjusting screw 22 by means of which it may be shifted relatively to the path of portion 18 so that the magnetic damping effect may be conveniently modified to suit requirements.

In the device shown at Figs. 3 and 4 the invention is embodied in a three-element vacuum tube in which the casing 23 has a stem part 24 from which the filament, plate, and grid of the tube are all properly supported. The filament 25 is suitably supported by the rod 26 while the rod 27 supports the plate 28 by means of the arms 29, and a lead 30 provides proper connection between the plate 28 and an appropriate contact (not shown) on the end of the plug 31. The grid of this tube comprises a member 32 carried by means of arms 33 from the aforesaid rod 27, and a relatively movable

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member 34 which has a flexible part 35 connecting it to the stem 24, has a weighted copper portion 36, and constitutes the pendulum or steady mass of the instrument. The part 32 is slotted or perforated at 37 and the part 34 is similarly slotted or perforated at 38 (see Fig. 3) so that relative movement between these parts 32, 34 results in a corresponding variation in the impedance in the vacuum tube and this variation is recorded or observed in any suitable or well-known manner at any convenient location. In this form of the device the magnetic damping is effected by means of an electromagnet 39 which is energized from any suitable source and by which the damping effect may be readily varied as circumstances may require.

In the device shown at Figs. 5 and 6 the casing 40 has a flattened waist part 41 for the reception of a damping magnet 42 which embraces a copper weight 43 on the member 44 of the pendulum or steady mass a metallic disc 45 is hermetically sealed in a month 46 at the end of the casing: In the position shown at Fig. 5, the atmospheric pressure on the exterior of the disc 45 holds a member 47 in position to prevent injury to the steady mass clue to vibration or concussion in transit. The member 47 is hermetically sealed to the disc 45 and has an external extension 48 which is screw threaded at its outer end for the reception of a nut 49 which bears against a sleeve 50 on a skeleton cover 51 fitted on the end of the casing. Relative rotation of the parts 48 and 50 is prevented by means of a pin 52 extending through a slot 53 in the extension 48 and through holes in the sleeve 50, and rotation of the nut 49 relatively to the cover 51 withdraws the member 47 from engagement with the steady mass and permits the latter to function in the desired manner and as hereinbefore described.

Figs. 7 and 8 show a device adapted for the recording of the horizontal

components of movements. The internal construction of this particular device is similar to that shown at Figs. 3 and 4 except that a permanent magnet 54 is illustrated instead of the electromagnet of Figs. 3 and 4, but it will, of course, be understood that any suitable form of damping means may be employed

in either form of the device; and each form of the device above described may be readily adapted for use in detecting either the vertical or the horizontal component of the motions.

What I claim is:-

1. A seismograph comprising a thermionic vacuum tube with one element thereof serving as a pendulum steady mass movable in only one plane, and external means for damping relative movement of the tube and the steady mass.

2. A seismograph comprising a thermionic vacuum tube with one element thereof serving as a pendulum steady mass movable only in a single plane and magnetic damping means for said mass.

3. A seismograph comprising a thermionic vacuum tube with one element thereof serving as a pendulum steady mass movable only in one plane, and variable magnetic damping means for the steady mass.

4. A seismograph comprising a thermionic vacuum tube with one element thereof serving as a pendulum steady mass movable only in a so single plane, and means within the tube for temporarily preventing the movement of the steady mass.

5. A seismograph consisting of a thermionic vacuum tube comprising a casing, an enclosed element fixed relatively to the casing, an enclosed element serving as a pendulum steady mass movable only in one plane, and external means for damping the relative movement of the said mass.

6. A seismograph consisting of a thermionic vacuum tube comprising a casing, an enclosed element fixed relative to the casing, an enclosed element serving as a pendulum steady mass movable in only a single plane, and variable external magnetic damping as means for the said mass.

7. A vibration-detecting instrument for detecting vibrations, consisting of a thermionic vacuum tube comprising a casing, an enclosed element fixed relatively to the casing, a damping-magnet mounted with its poles embracing a part of the vacuum tube, and a relatively movable element comprising a flexible portion which permits movement only in a single plane and a copper portion located between the poles of the said magnet.

8. A vibration -detecting instrument for detecting vibrations, consisting of a thermionic vacuum tube comprising a casing, enclosed elements fixed relatively to the casing, a damping electro-magnet mounted with its poles embracing a part of the vacuum tube, and a relatively movable element comprising a flexible portion anchored in the tube to permit movement of such element only in a single plane, and a weighted end portion of copper located between the poles of the Said electromagnet.

In testimony whereof I have signed my name to this specification.

OLIVE SCOTT PETTY.

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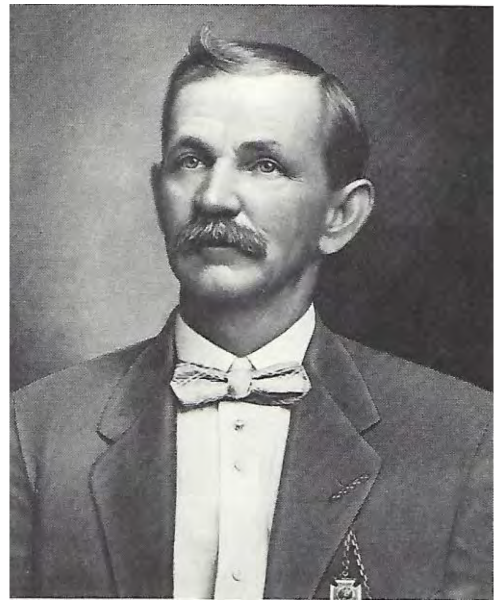
Appendix D
Biographies

Bigraphies



Van A. Petty, Sr.

VAN ALVIN PETTY, SR. (1860-1929). Members of the Petty family have been developers of Texas' natural resources since 1881 when Van Alvin Petty, Sf. began his career in the lumber industry in East Texas. He was born at Bastrop, Texas, August 19, 1860. He married Mary Cordelia Dabney, a native of Selma, Texas. His father, a prominent lawyer of the period, who came to Texas in 1852, became a Captain in the Confederate Army and was killed in the battle of Pleasant Hill in Louisiana.

Van A. Petty. Jr.

Van Alvin Petty, Jr. was born at Orange, Texas, March 14, 1889, son of Van Alvin and Mary Cordelia (Dabney) Petty. He was graduated L.L.B. from Cumberland University, Lebanon, Tennessee in 1913 and was admitted to the bar in Kentucky and Texas. Immediately upon graduation he opened his own law office in San Antonio. The oil business was his first love, however, and he became an independent oil operator while continuing to practice law.

In 1911 he married Estelle Edna George, a native of Lake Charles, Louisiana. They had two children: Mary Estelle (Mrs. Reagan Tucker) and Van Alvin Petty, III. Mr. Petty formed several oil companies, among them the Olive Petroleum Company, The Old Dominion Exploration Company, and the Petty Oil Corporation.

When Petty Geophysical Engineering Company was founded he was responsible for setting up the charter under which it operated throughout its corporate life. He served as vice president and chief counsel and as a director of Petty Geophysical until his death. He was known and respected throughout the oil industry, by both major and independent companies, and because of this was able to negotiate the company's early contracts which were vital to its success. He was a member of many professional organizations, an Honorary Texas Ranger, a member of Sigma Alpha Epsilon Fraternity, and a member of the Baptist Church.

Biographies

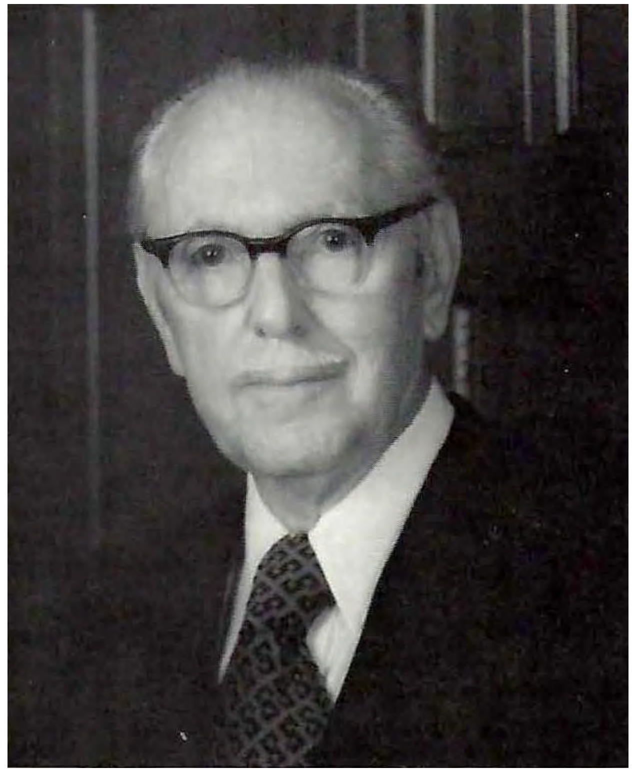
DABNEY E. PETTY (1891-1963) was born at Olive, Hardin County, Texas, June 29, 1891. He received his college education at Georgia Institute of Technology, The University of Texas, and Cornell University. He married Ona Stephens of Madisonville, Texas, and they had one son, Noel. At the start of World War I he was doing exploration geology in South America and was exempt from the draft but his patriotism was such that he resigned his position to return to the States and volunteer as a private in the Engineer Corps. He served in France until he was wounded and spent a year in army hospitals. After his recovery he attended Cornell University studying and teaching geology.

Upon leaving Cornell Mr. Petty decided to try to find an oil field for himself. He decided that the most likely place would be on the West Coast of Africa for two reasons: (1) he knew the geology was favorable there and (2) because it was the least explored and most dangerous place on earth, it should be virgin hunting territory. Also he loved hunting and fishing and dangerous excitement. His search took him into cannibal country 400 miles into the interior where no white man had ever been before. He traveled alone, carrying the few necessities of life on his own back, the only white man within several hundred miles. He found what he was looking for, one of the great oil fields of the world, and returned with a half-gallon bottle of high gravity crude oil, but he was ahead of his time and could never get anyone with sufficient capital to develop it.

After his return from Africa Mr. Petty worked for about a year as a consulting geologist before accepting the position as Associate State Geologist with the Bureau of Economic Geology at Austin, from which he resigned in 1925 to help found Petty Geophysical Engineering Company. He was a member of Theta Xi and Sigma Gamma Epsilon Fraternities and of the Baptist Church

Dabney E. Petty

OLIVE SCOTT PETTY was born at Olive, Hardin County, Texas, on April 15, 1895, son of Van Alvin and Mary Cordelia (Dabney) Petty. He attended Georgia Inst. of Technology in 1913-14 and took his Bachelor's degree in Civil Engineering from the University of Texas in 1917 and the advanced degree of Civil Engineer in 1920. Mr. Petty served as an officer in the Corps of Engineers in France in World War I. He married Mary Edwina Harris in 1921 and they have one son, Scott Petty, Jr. He was Adjunct Professor of Civil Engineering at the University of Texas 1921-23 and Structural Engineer with R.O. Jameson in Dallas 1923-25. He was President and Board Chairman of Petty Geophysical Engineering Company 1925-52 and Chairman 1952-73. Currently he is geophysical consultant to Petty-Ray Geophysical. Mr. Petty is a member of numerous professional and scientific organizations, among them being:



O. Scott Petty

Soc. of Exploration Geophysicists (Honorary Life and Charter Member) Amer. Soc. of Civil Engineers (Hon. Life), Amer. Inst. of Mining Engineers (Mem. Legion of Honor), Soc. of Petroleum Engineers (Mem. Legion of Honor), Texas Mid-Continent Oil and Gas Assn. (Director), Recipient of the distinguished Graduate Award, Univ. of Texas 1962, Registered Prof. Engineer State of Texas. He is an honorary life member of the Advisory Council to the Geology Foundation, Univ. of Texas, and a founding member and member of (he Executive Committee of (he Chancellor's Council of The University of Texas at Austin. He has been listed in Who's Who in America and is currently listed in Who's Who in the South and Southwest, Who's Who in Finance and Industry, and American Men of Science. He is a member of Theta Xi, Tau Beta Pi and Chi Epsilon (Honorary Life) Fraternities and a member of the Baptist Church but attends the Episcopal Church.

Edwina H. Petty

SCOTT PETTY, JR. was born in San Antonio, Texas, on April 10, 1937, son of Olive Scott and Edwina (Harris) Petty. He attended The University of Texas and took his B.S. degree in Petroleum Engineering in 1960 and his M. S. in 1961. He married Marie Louise James in 1959 and they have three children- Joan Louise, Susan Harris, and Scott James. He served as lieutenant in the Corps of Engineers, AUS 1959-60. He joined Petty Geophysical Engineering Company in 1961 and became its President in 1967, a position he held until 1973 when the company was merged into Geosource Inc. and was integrated with the Ray Geophysical Division to form what is now Petty-Ray Geophysical Division. Currently, he is self-employed in San Antonio and a consultant to the President of Geosource Inc. He is a registered Professional Engineer, Texas, and Louisiana, and is a member of the Society of Exploration Geophysicists, European Association of Exploration Geophysicists, American Association of Petroleum Geologists, American Institute of Mining, Metallurgical and Petroleum Engineers, and the Society of American Military Engineers. He is listed in Who's Who in the South and Southwest, Who's Who in Finance and Industry, and Leaders in American Science. He is currently a member of the Board of Directors of the Bexar County National Bank, San Antonio Savings Association, C.H. Guenther & Sons, Inc. (Pioneer Flour Mills), and the International Association of Geophysical Contractors. He is a member of Phi Gamma Delta, Sigma Gamma Epsilon, and Tau Beta Pi Fraternities and is a member of the Episcopal Church.

Scott Petty Jr.

VAN A. PETTY, III was born in San Antonio on August 18, 1914, son of Van A. Petty, Jr. and Estelle Edna (George) Petty. He spent a short period with Petty Geophysical Engineering Company before entering the University of Texas from which he graduated with the B.S. and M.A. degrees majoring in geology. He married Maxine Lambert, native of Shawnee, Oklahoma. They have three daughters: Patricia Estelle (Mrs. Allan R. Zinsmeyer, Jr.), Maxine Mary (Mrs. John W. Kenney) and Christine Sharon (Mrs. Chauncey W. Pal. After experience with the Navarro Oil Company and Union Producing Company he rejoined Petty in 1942 as vice president and Director and remained with them until 1955 when he resigned to become an independent consultant. He continued as a Director until 1973. He is a member of the South Texas Geological Society, American Association of Petroleum Geologists, Society of Exploration Geophysicists and Sigma Gamma Epsilon. He is an associate member of Sigma Xi and the Scientific Research Society of America. He is listed in Who's Who in the South and Southwest, Who's Who in Finance and Industry and Personalities of the South and is a member of the Episcopal Church.

Van A. Petty. III